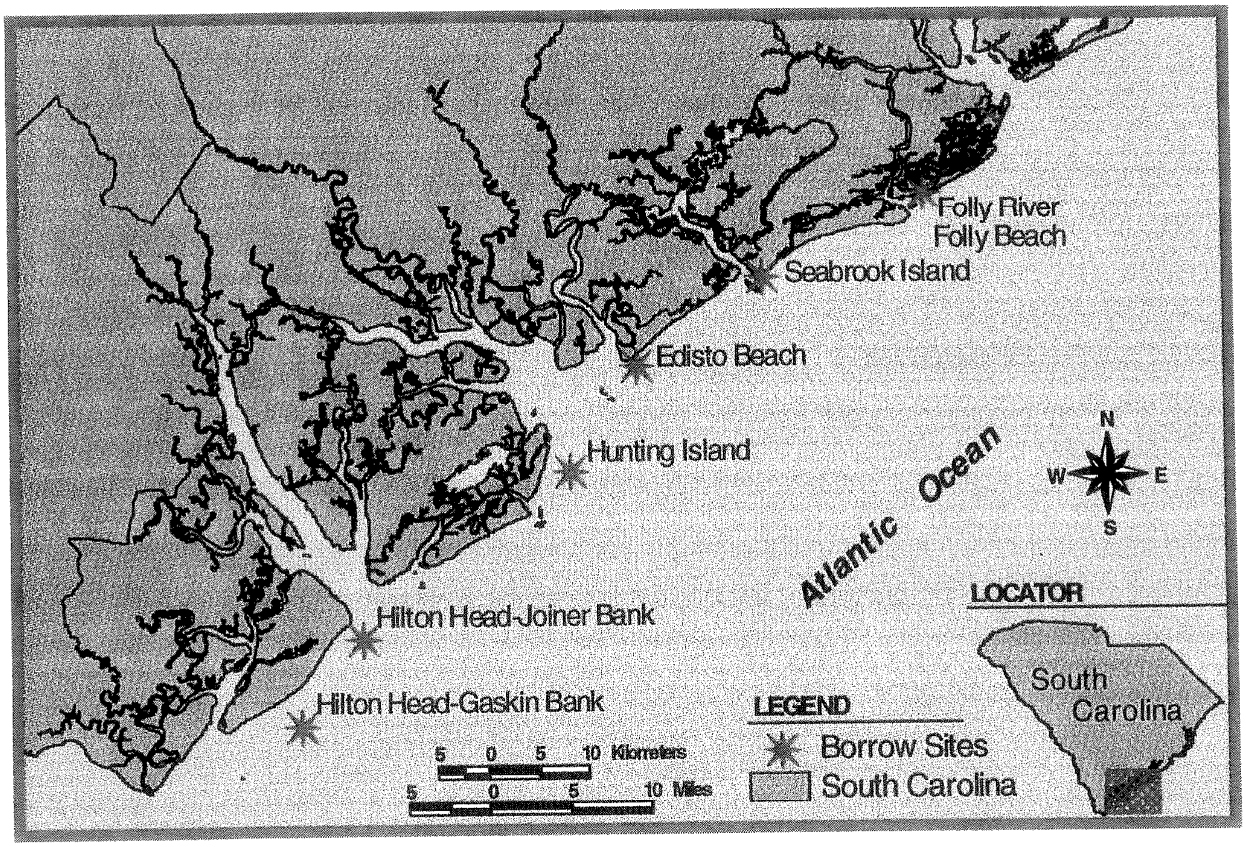
An Evaluation of Physical Recovery Rates in Sand Borrow Sites Used for Beach Nourishment Projects in South Carolina

prepared by

R.F. Van Dolah, B.J. Digre, P.T. Gayes,
P. Donovan-Ealy and M.W. Dowd



FINAL REPORT

Submitted to
The South Carolina Task Force on Offshore Resources
and the
Minerals Management Service
Office of International Activities and Marine Minerals

Final Report

An Evaluation of Physical Recovery Rates in Sand Borrow Sites Used for Beach Nourishment Projects in South Carolina

By

Robert F. Van Dolah and Brad J. Digre
Marine Resources Research Institute
S.C. Department of Natural Resources
P.O. Box 12559
Charleston, SC 29422

Paul T. Gayes and Patricia Donovan-Ealy
Center for Marine and Wetland Studies
Coastal Carolina University
P.O. Box 1954
Conway, SC 29526

And

Millard W. Dowd
U.S. Army Corps of Engineers, Charleston District
P.O. Box 919
Charleston, SC 29402

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EXECUTIVE SUMMARY

Beach nourishment projects completed to date in South Carolina have generally utilized sand borrow sites located in nearshore shoals off the beach that was nourished. The physical and biological recovery of sand borrow sites have not been well documented for most of these projects. Data from a limited number of studies in other areas of the coastal United States suggest that sand borrow sites generally refill at very slow rates and often with finer-grained material that may not be compatible for future renourishment projects. Biological recovery may be more variable and most prolonged where bottom sediment composition changes significantly. Two monitoring projects recently completed in South Carolina found significant changes in bottom sediment characteristics (large increases in the percentage of muddy sediments) following dredging operations for beach nourishment. These physical changes were accompanied by significant changes in the benthic communities.

This study examined six sand borrow sites that had been dredged in South Carolina over the past eight years in order to (1) document the present size and configuration of each borrow site, (2) determine changes in the volume of sediments that had occurred over time, and (3) document the composition of surficial sediments in each borrow area. All published and non-published information available for each site was used to define the initial configuration and size of the dredged hole. Historical post-dredge surveys available for a few of the areas, combined with new bathymetric surveys completed in 1996 at five of the areas, were then used to evaluate post-dredging changes in bottom topography. The 1996 surveys also included collection of surficial sediments from five of the sites and vibracores samples from two of the sites, to evaluate surficial and subsurface sediment composition. All bathymetric data were analyzed using Geographic Information System (GIS) processing techniques to build bottom contour profiles and changes in sediment volumes over time.

The bathymetric and surficial sediment surveys showed a wide diversity of filling rates and depositional sediment types among the six areas examined (Table 12). Four of the six sites considered (two off Hilton Head Island, one off Hunting Island, and one in the Folly River behind Folly Island) were refilling at rates that would require between 5.5-11.8 years to completely refill to pre-dredge profiles. Another site off Edisto Island was refilling at a relatively rapid rate (1.75 yrs), probably due to its small size combined with location of this site in a depositional shoal at the southern end of the island. This sixth site off Seabrook Island also appeared to have largely refilled by the 1996 survey, but data available for this site were too limited to confirm this.

Our study results suggest that locating sand borrow sites in highly depositional shoals at the southern ends of these islands may increase the rate of refilling borrow areas. Much of the sand located on the beach and in the nearshore zone of these islands would typically be transported in a southerly direction, and tend to accumulate in the depositional shoals at the southern end of the island. In contrast, the area showing the slowest recovery (Gaskin Banks off Hilton Head Island) is located further offshore and near the center of that island.

Surficial sediments at all of the borrow sites consisted of clean sands that would be suitable for future nourishment projects. However, three of the sites (Folly, Hunting, and Joiner off Hilton Head Island) may have surficial sands covering one or more lenses of mud based on previous studies. Muddy sands are not considered to be suitable for use in beach nourishment projects. Thus, these areas would need to be avoided in the future or dredged only to depths above the muddy layer. The need to relocate borrow sites for future renourishment projects would result in disturbance of more bottom than would be the case if the same borrow area could be re-used over time. Since many of the beach nourishment programs in South Carolina require renourishment at 5-8 year intervals, locating future borrow sites in areas that are likely to fill with beach compatible sands during the time period between nourishment projects would be highly desirable.

INTRODUCTION

Beach nourishment projects conducted in South Carolina and other states generally have been completed by dredging sands from nearshore shoals. The size and depth of the resulting sand-borrow pits have varied greatly among projects dependent on the volume of sand needed. In South Carolina, most of the sand-borrow areas that have been dredged to date range in size from approximately 12 acres (4.8 ha) to 214 acres (86.6 ha). The majority of these sites have been dredged to depths 10 ft (3.1 m) or more below the existing bottom grade.

The physical and biological recovery of sand borrow sites has not been well documented. Data from a limited number of physical surveys conducted in the U.S. coastal zone suggest that these areas generally refill at very slow rates and often with finer-grained materials than were present previously (see National Research Council, 1995 for review). Biological studies completed in some of these borrow sites and other dredged sites have documented recovery rates that are quite variable, with effects often lasting more than one year after dredging (see National Research Council, 1995 for review). Areas where impacts were greatest and most prolonged were often associated with changes in bottom sediment composition.

In South Carolina, several of the more recently completed nourishment projects have been monitored to document changes that occurred in the sand borrow areas and on the beach (see Van Dolah et. al., 1994 for review). A few of these studies documented relatively long-term (> 1yr) changes in the composition of both the sediments and biota following dredging activities. Changes in the biological resources in one site (Joiner Bank Borrow Site, Hilton Head Island) were considered to be undesirable since substantial alterations in the composition of bottom fauna may have affected their trophic function (Van Dolah *et al*, 1992). The increased percentage of muddy sediments at this site and in the Folly River borrow site (Van Dolah *et al.*, 1994) was also considered to be undesirable since it is likely that these areas would not be able to be reused in future beach nourishment projects.

Most of the sand-borrow sites in South Carolina have not been monitored to document their refilling rates. Therefore, a better understanding of how these areas change over time, both in terms of refilling rates and the type of sediments being deposited, is critically needed to avoid long-term modification of the state's nearshore coastal resources in future nourishment projects.

This report summarizes the results of recent surveys completed at six sand-borrow sites that were dredged in the last eight years along the South Carolina coastline (Figure 1). The primary objectives of these surveys were to:

- document the present size and configuration of each borrow site to determine changes in the volume of sediments that occurred over time, and
- document the composition of surficial sediments in each borrow area.

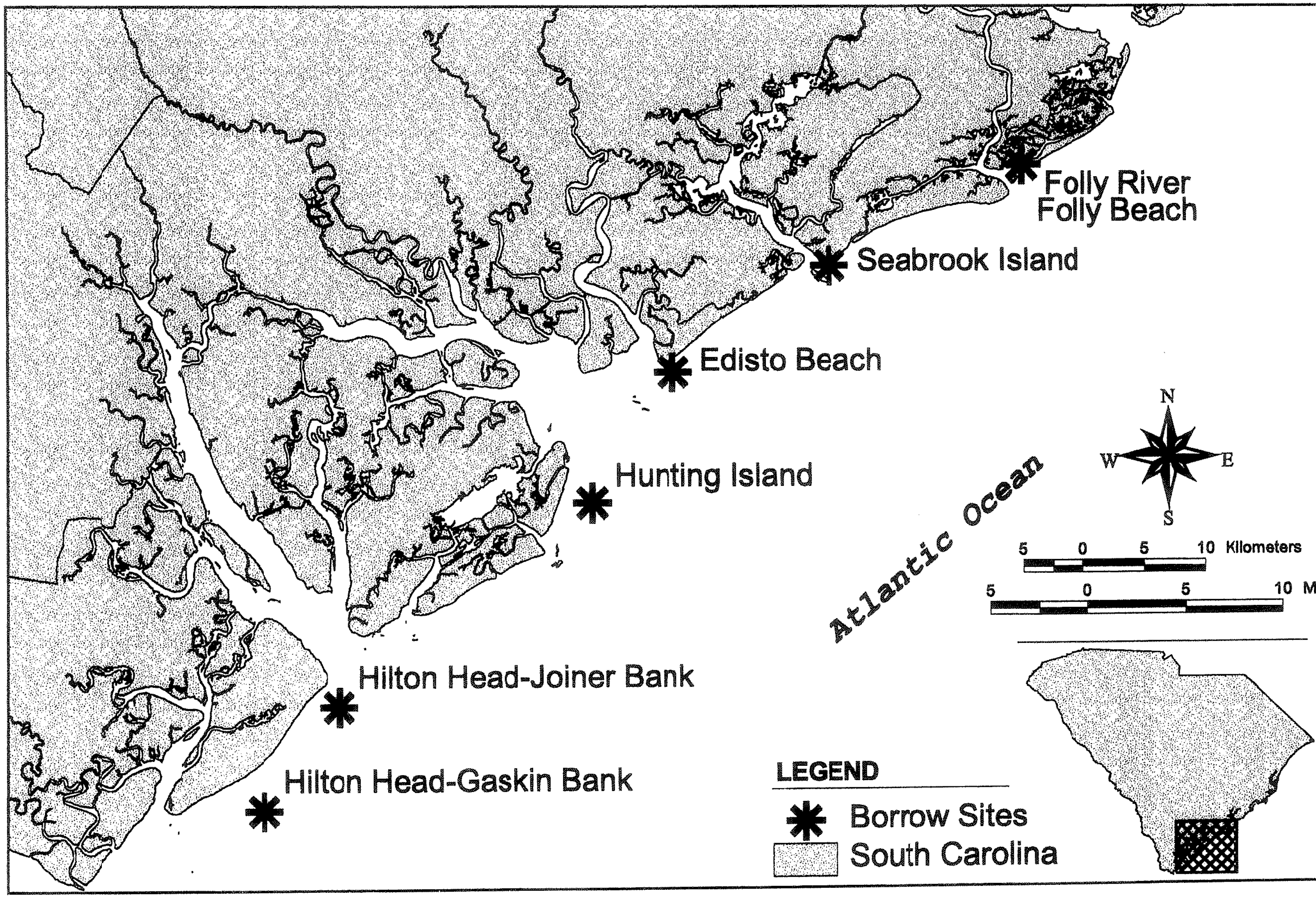

Figure 1. Locations of six South Carolina beach renourishment borrow areas that were evaluated.

METHODS

General Approach:

The six sand-borrow sites selected for study represent all of the areas that have been dredged for beach nourishment projects over the last decade in South Carolina. One site was located in the Folly River, an estuarine area located behind Folly Beach, S.C. The other five sites were located in nearshore shoals off Hilton Head Island (two locations), Edisto Island, Hunting Island, and Seabrook Island (Figure 1).

All published and unpublished historical information available for each of the borrow sites was obtained in order to define the configuration and size of the dredged areas. Bathymetric surveys of the five nearshore shoals were then completed in 1996 by the Coastal Carolina University (CCU) Center for Marine and Wetland Studies (CMWS) to document bottom topography in and immediately around each of the borrow sites in 1996. Surficial sediment samples were also collected at several locations in each borrow area during the surveys to document sediment composition. The inshore borrow site located in the Folly River was surveyed by the U.S. Army Corps of Engineers (USACOE), Charleston District in 1992, prior to the Folly Beach Nourishment Project, and then annually from 1993 to 1996 following dredging for this project. Therefore, this area was not resurveyed by the CMWS.

The bathymetric data collected by the CMWS and the USACOE were provided to the S.C. Department of Natural Resources, Marine Resources Division (SCDNR-MRD) for further processing using Geographic Information System (GIS) processing techniques. More specific information on the survey protocols, bottom sampling techniques, and the data analyses completed for each area are provided in the following sections.

Bathymetric Surveys:

Folly River Borrow Area:

The Folly River borrow area was dredged during the winter of 1992-1993 to provide sand for the Folly Beach Nourishment project, which encompassed most of that island's front beach. The borrow area extended along the length of the river from a point near Bird Key island to an area behind Folly Island near the Folly Marina (Figure 2). Approximately 214 acres (86.6 ha) of bottom habitat were dredged to an average depth of about 14 ft (4.3 m) below National Geodetic Vertical Datum of 1929 (NGVD).

As part of a multi-agency monitoring effort, the USACOE Charleston District completed six bathymetric surveys of the borrow area. These surveys provided the most comprehensive database available among all six of the borrow areas studied. The Folly River site also represents the only inshore dredging operation where data have been collected in South Carolina to track physical recovery patterns over time.

All surveys were completed using the Corp's survey vessel *Wilson*, which was equipped with an Innerspace Model 49 fathomether system and a Krupp Atlas "Polartrak" range-azimuth positioning system. Tidal height was standardized by use of a staff gauge on site. Approximately 75 shore-perpendicular transects were completed during each survey period using a 200 ft (61 m) line spacing for most of surveys. All transect lines encompassed the adjacent bottom shoals where depth permitted the vessel to operate. The dates of each survey were as follows:

Date	*Approximate Period Represented*
December 3-4, 1992	Shortly before dredging commenced
May 11-12, 1993	Shortly after dredging was completed
October 19-20, 1993	Six months after dredging was completed
May 26-June 1, 1994	One year after dredging was completed
February 22-24, 1995	Two years after dredging was completed
August 6, 1996	Three years after dredging was completed

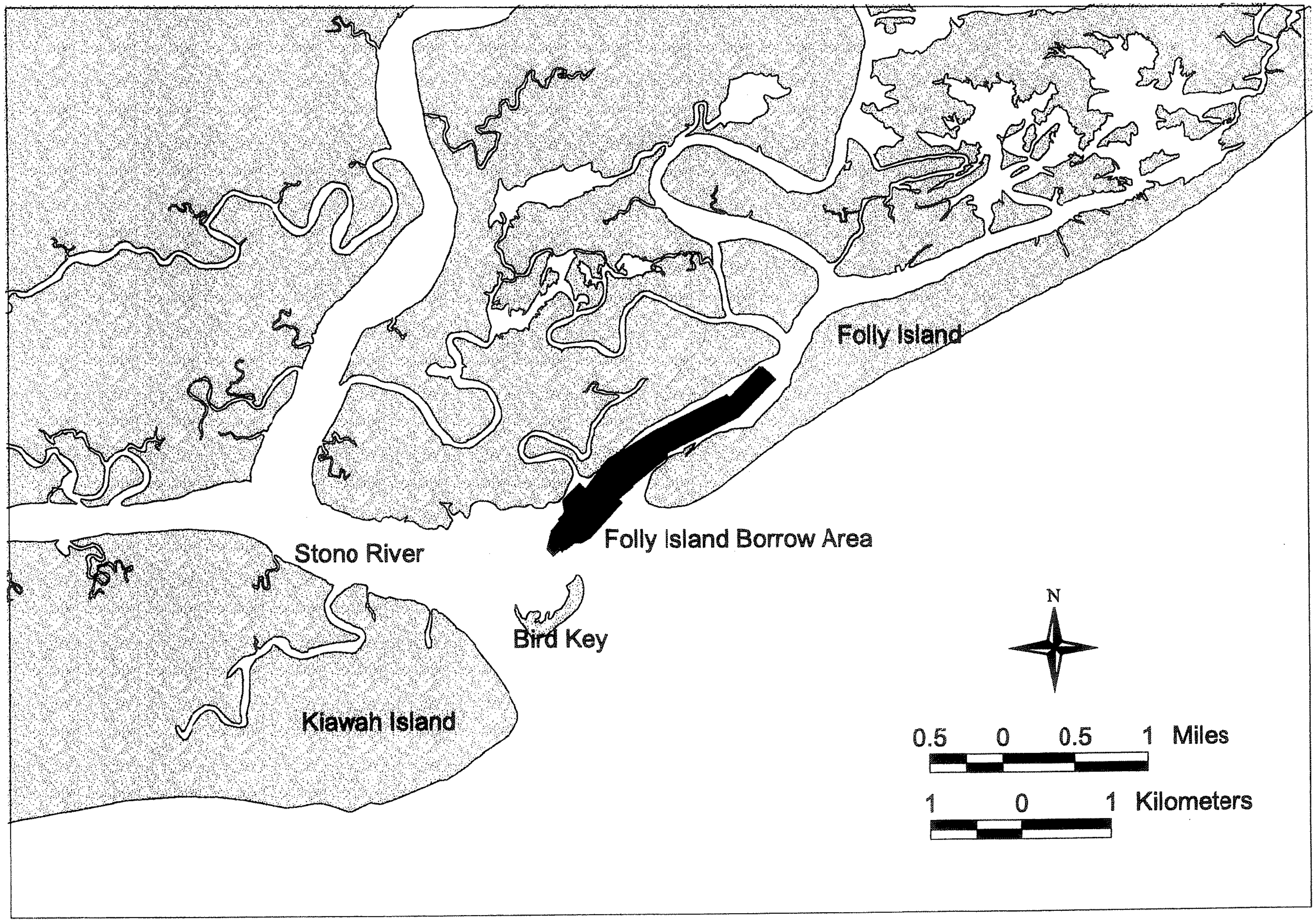

Figure 2. Location of the Folly River borrow area that was dredged in 1992-1993.

Hilton Head Island: Gaskin Banks and Joiner Bank Borrow Areas:

Two borrow areas were dredged for the Hilton Head Beach Nourishment Project which was completed during the spring and summer of 1989-1990 (Figure 3). One site was located at the Joiner Bank shoal near the mouth of Port Royal Sound and encompassed approximately 82 acres (33.2 ha) of bottom habitat. The other site was located at the Gaskin Banks shoal, which is situated approximately two nautical miles (3.7 km) off the beach near the center of the island. Dredging at this site encompassed approximately 113 acres (45.7 ha) of bottom habitat. Joiner and Gaskin Banks were dredged to a depth of approximately -18 and -20 ft (-5.5 and -6.1 m) NGVD respectively, which was approximately 10 ft (3.1 m) below the existing bottom grade.

Olsen Associates, Inc. (Jacksonville, FL) completed a limited survey in 1988 to evaluate both shoals and other locations as possible borrow areas. Specific survey protocols are not published, but the data provide the only pre-construction information available for the area.

Olsen Associates, Inc. also coordinated a more comprehensive survey in 1994 to map the offshore bathymetry within 10 miles (16 km) of the coastline from the southern end of Phillips Island to the northern bank of the Savannah River Entrance Channel (Creed, 1995). The landward and seaward limits of the survey area were approximately equivalent to the -5 ft and -50 ft (-1.5 and -15.2 m) NGVD, respectively. The survey included both "high resolution" and "low resolution" areas. The high resolution areas encompassed Gaskin Banks, an area seaward of the emergent portion of Joiner Bank, and Barrett Shoals (Creed 1995). Although the objectives of this study were not centered on evaluating recovery rates of the two areas dredged in 1990, the data provide an excellent database for evaluation of the bathymetric conditions in each area approximately four years after dredging.

All survey activities were conducted from May to July, 1994 by a subcontractor (ARC Surveying and Mapping, Inc., Jacksonville, FL). The survey data were collected along shore-perpendicular lines spaced approximately 3000 ft (914 m) apart within the low resolution areas and approximately 1500 ft (457 m) apart within the high resolution areas. This provided over 450 line-miles (724 km) of data. Depth soundings were collected using an Innerspace 449 fathometer. Real-time, sub-meter horizontal position data were produced with a Trimble 4000 SE Differential Global Positioning System (DGPS) and Coastal Oceanographic's HYPACK software was used to collect and post-process both the bathymetric and horizontal position data. Average spacing between soundings was about two feet (0.6 m), and elevations were computed relative to the National Geodetic Vertical Datum (NGVD) of 1929. The horizontal location of all soundings were relative to the South Carolina NAD 1983 horizontal state plane coordinate system (Creed, 1995).

A second post-dredging survey was completed by the CMWS as part of our study to obtain additional information on filling rates in the two borrow areas. Depth data were collected using an Innerspace 448 fathometer with a 208 kHz transducer. Positioning data were collected using a Trimble ProXL with real time differential corrections from a station in Charleston, SC. The surveys were conducted during calm seas, although standing waves in some portions of the Joiner Bank shoals were greater due to shallow water depths. Soundings were collected every 2-4 ft (0.6-1.2 m) along planned survey lines that were 200 ft (61 m) apart in both borrow areas. Due to a difference in the size of each area, 32 transect lines were surveyed at the Gaskin Banks site and 15 transect lines were surveyed at Joiner Bank site. Data collection and post-field processing were completed using HYPACK software (Coastal Oceanographics, Inc.).

Elevations were standardized using a MicroTide solid state tide gauge that was placed at a marina on Hilton Head Island during the bathymetric survey. This tide gauge measured water elevation with 0.1% accuracy using an ICS strain gauge pressure sensor. Tidal elevation was initially calibrated by surveying from an OCRM benchmark located on the front beach of the island and the data were adjusted to NGVD elevations.

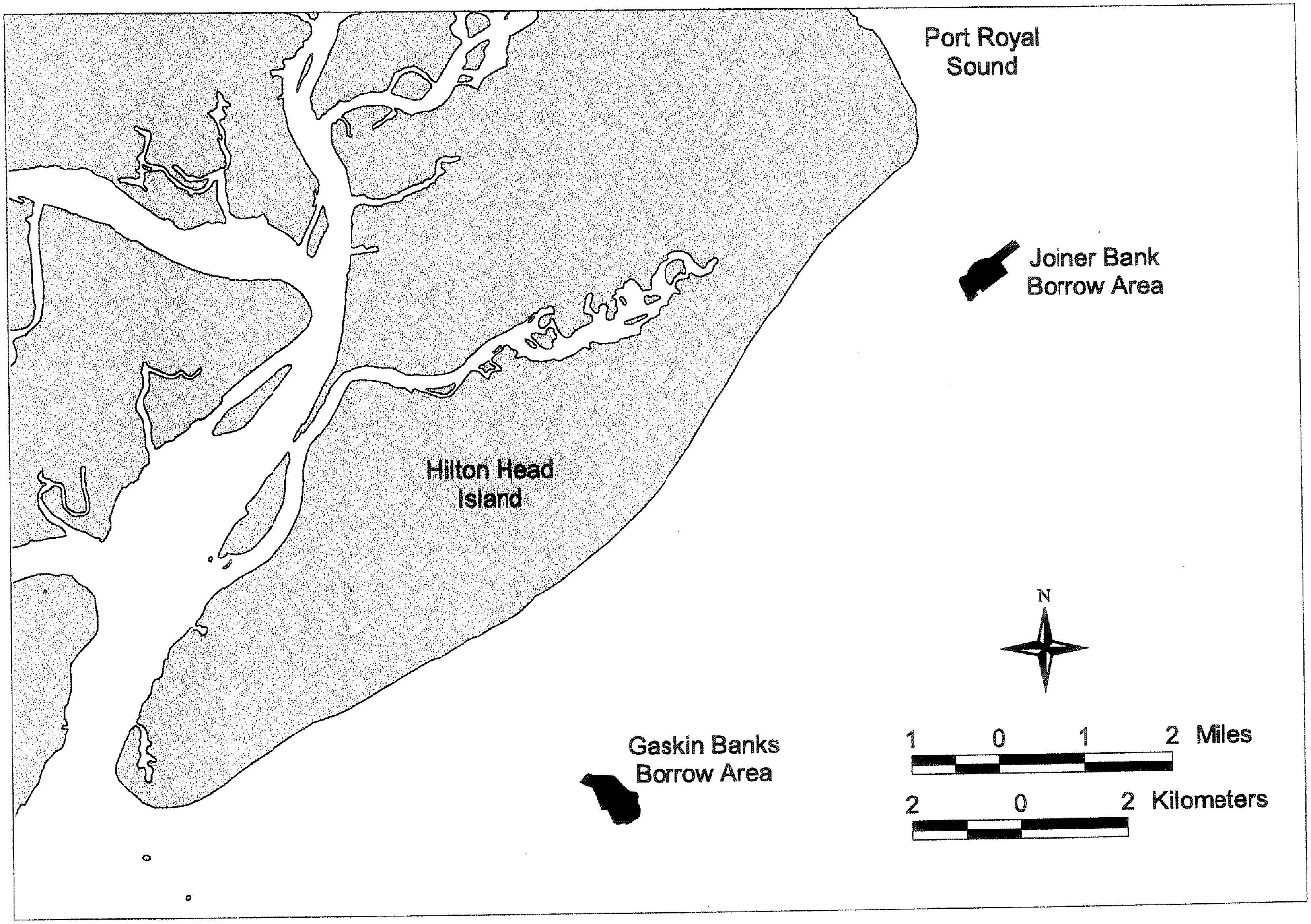

Figure 3. Location of the Hilton Head borrow areas that were dredged in 1990.

Edisto Island, Hunting Island and Seabrook Island Borrow Areas:

The Edisto Island, Hunting Island and Seabrook Island beach nourishment projects were completed during the winter and/or spring of 1995, 1991, and 1990, respectively. All of these areas were located in nearshore shoals less than two miles (3.2 km) from the beach (Figures 4-6). The borrow sites ranged in size from 12 acres (4.9 ha) to 56 (22.7 ha) acres and were dredged to depths of 15-21 ft (4.6-6.4 m) below NGVD.

No comprehensive bathymetry data were available for these sites prior to this study. However, information on the shape and size of the borrow sites was provided in contract reports prepared by the consulting firm coordinating each project (Coastal Science and Engineering [CSE]-Baird, 1996; Coastal Science and Engineering, 1989, 1991, 1996a, 1996b). In order to obtain information on the current configuration of each borrow area, surveys were completed by the CMWS during May – June, 1996. Survey protocols were identical to those described for the Hilton Head borrow areas with the following exceptions:

- At the Edisto Island borrow area, 14 transect lines were surveyed with the lines spaced approximately 200 ft (61 m) apart. A Seatex MRU-6 heave/pitch/roll compensator was used for a portion of this survey to help compensate for problems related to relatively large standing waves.
- Survey lines at the Hunting Island site were also spaced 200 ft (61 m) apart and 13 transects were completed.
- Due to its small size, 10 transects were completed at the Seabrook Island site, with the line spaced 100 ft (30 m) apart. A MicroTide tide gauge was used to calibrate bottom elevations with sea level conditions at the Edisto and Hunting Island sites as described above. The Seabrook Island borrow site data was tide corrected with time and location adjustments using tide data from the Charleston station and NOAA tide tables.

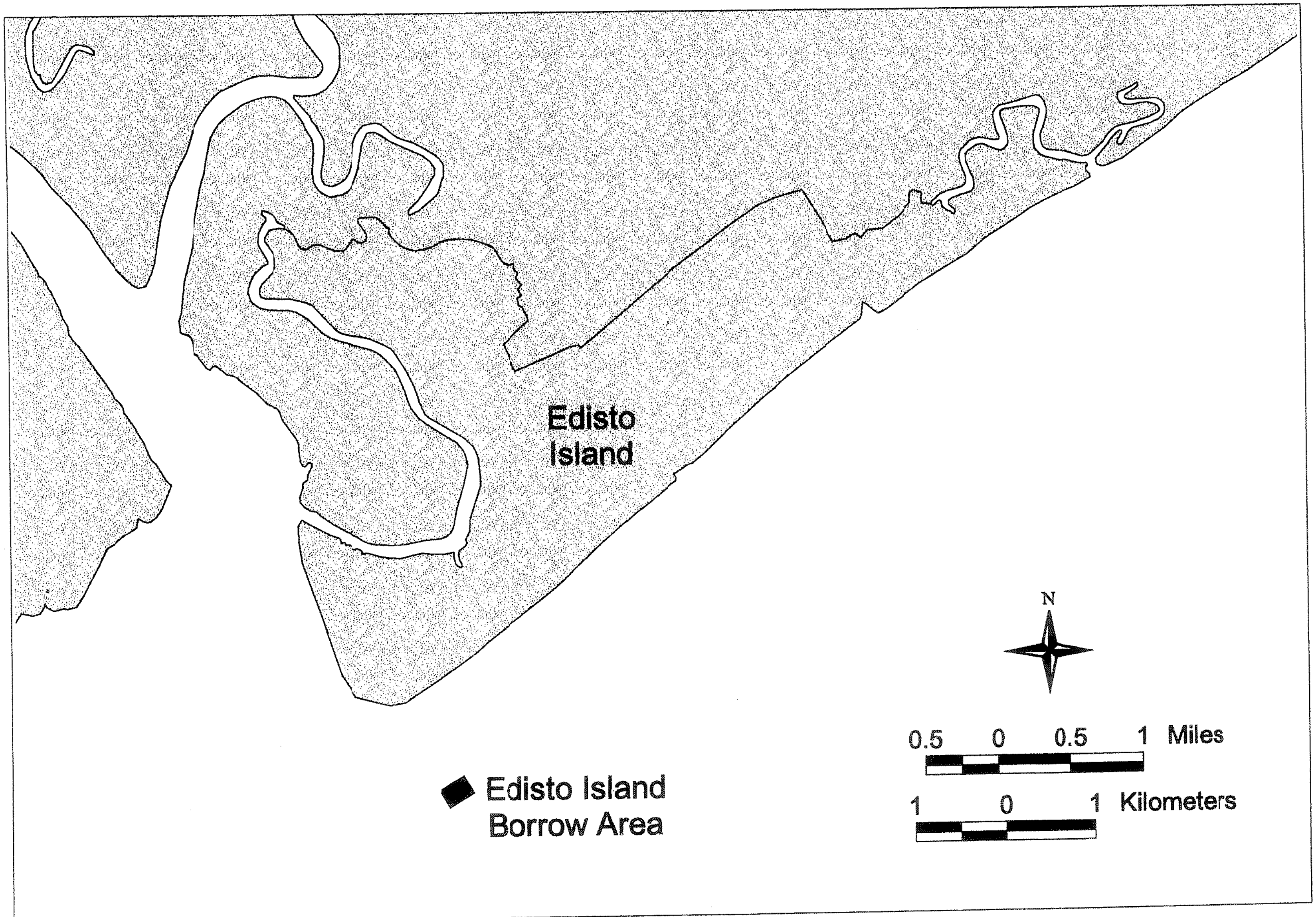

Figure 4. Location of the Edisto Island borrow area that was dredged in 1995.

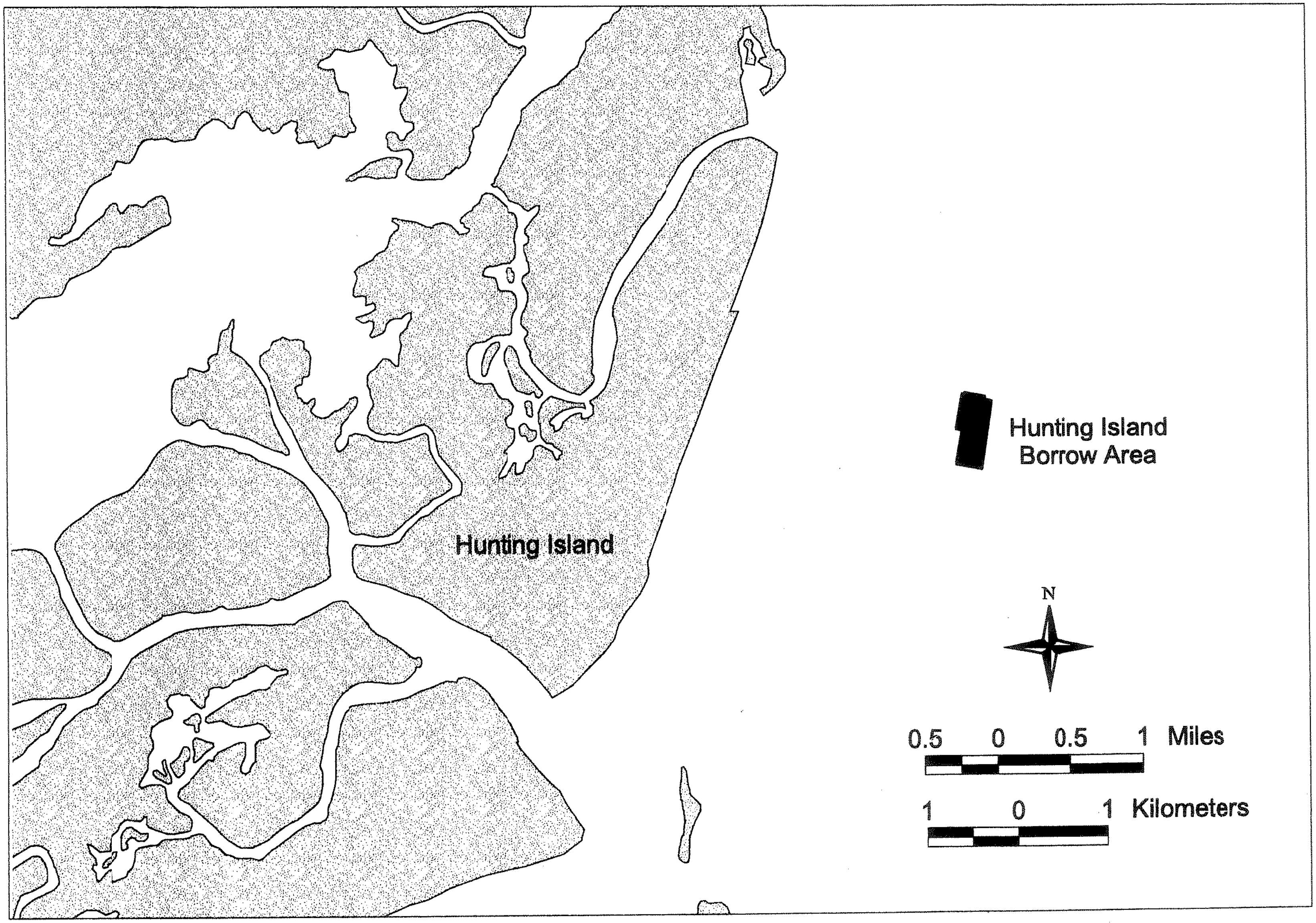

Figure 5. Location of the Hunting Island borrow area that was dredged in 1991.

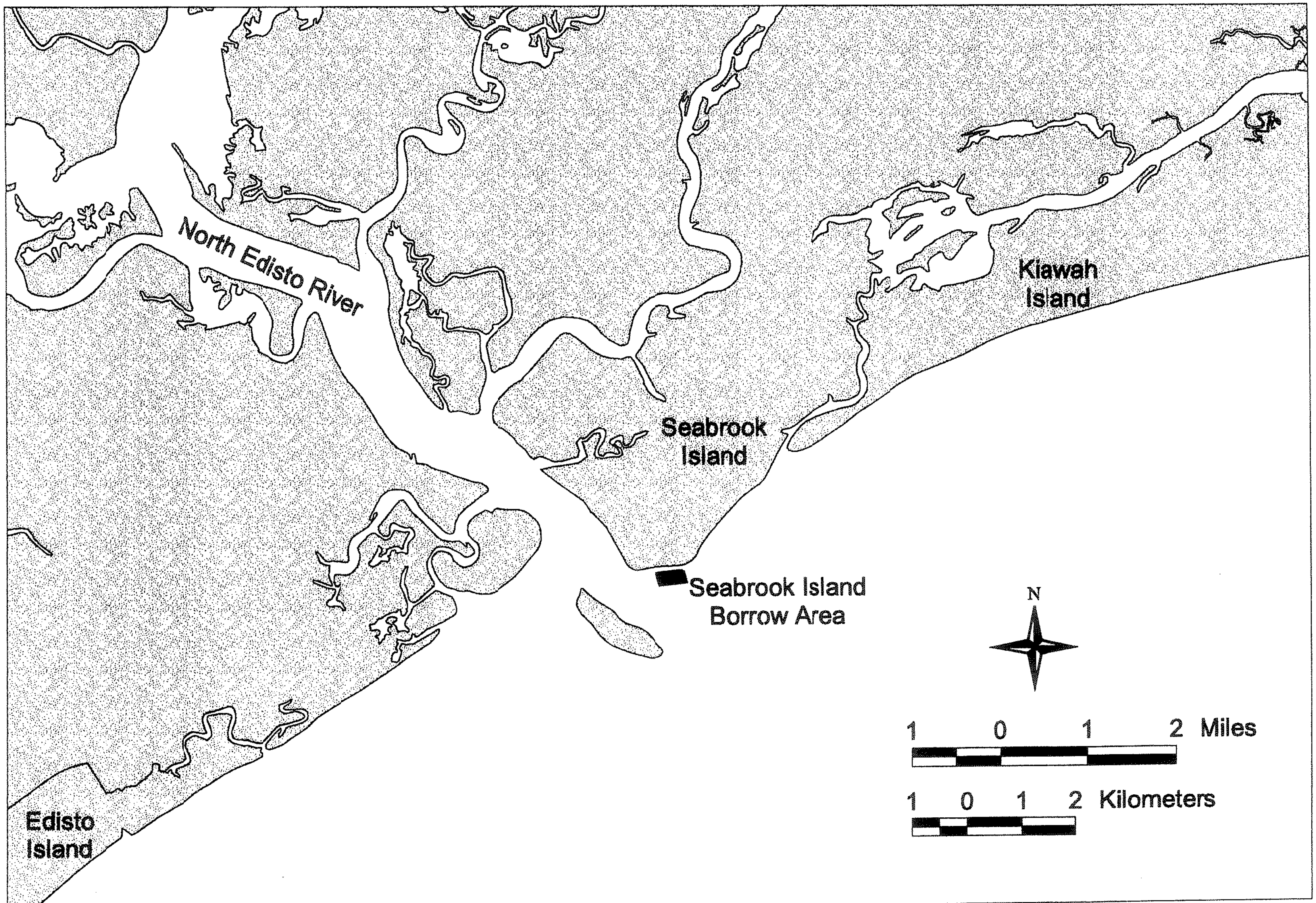

Figure 6. Location of the Seabrook Island borrow area that was dredged in 1989.

Bathymetric Data Processing:

All data collected from the various bathymetric surveys were processed using ARC/INFO (Environmental Systems Research Institute, Version 7.0.4) on a SUN SPARCstation 20. Due to the variety of bathymetric survey methods and quality of data available for each borrow area, different procedures were used to compute changes in the bottom bathymetry and filling rates. Detailed flowcharts describing the GIS processing method used for five of the borrow sites are provided in Figures 7-11, and summarized in the following sections. The Seabrook Island site was not analyzed in the same manner due to limitations in the data available.

Folly River Borrow Site:

Bathymetric data from the Folly River borrow site consisted of immediate pre- and post-dredge surveys. This allowed for very accurate construction of the borrow site dimensions and depth. The bathymetry data for each survey period were first organized as mass points [STEP 1 - Figure 7] to create a Triangulated Irregular Network (TIN) [STEP 2]. The TIN data structure allows for the efficient generation of surface models for the analysis and display of terrain and other types of surfaces (ESRI 1991). The command <DESCRIBETIN> was used to verify the TIN model [STEP 2-a].

TIN surfaces were then converted to a GRID [STEP 3], which is a cell-based geoprocessing method that can accurately portray continuous surfaces (ESRI 1991). The <TINLATTICE> {linear} command was used to interpolate z values from the TIN using a cell size of 5 ft. This cell size gave the best resolution without over-tasking the computer's hard-disk-space limitations. In order to conserve additional disk space, the floating point LATTICE's were rounded to the next lowest whole value to create integer GRID's. This enabled us to convert a 20-Megabyte (Mb) floating point LATTICE to roughly a 1-Mb integer GRID.

The boundary of the site was defined [STEP 4] using coordinates provided by the

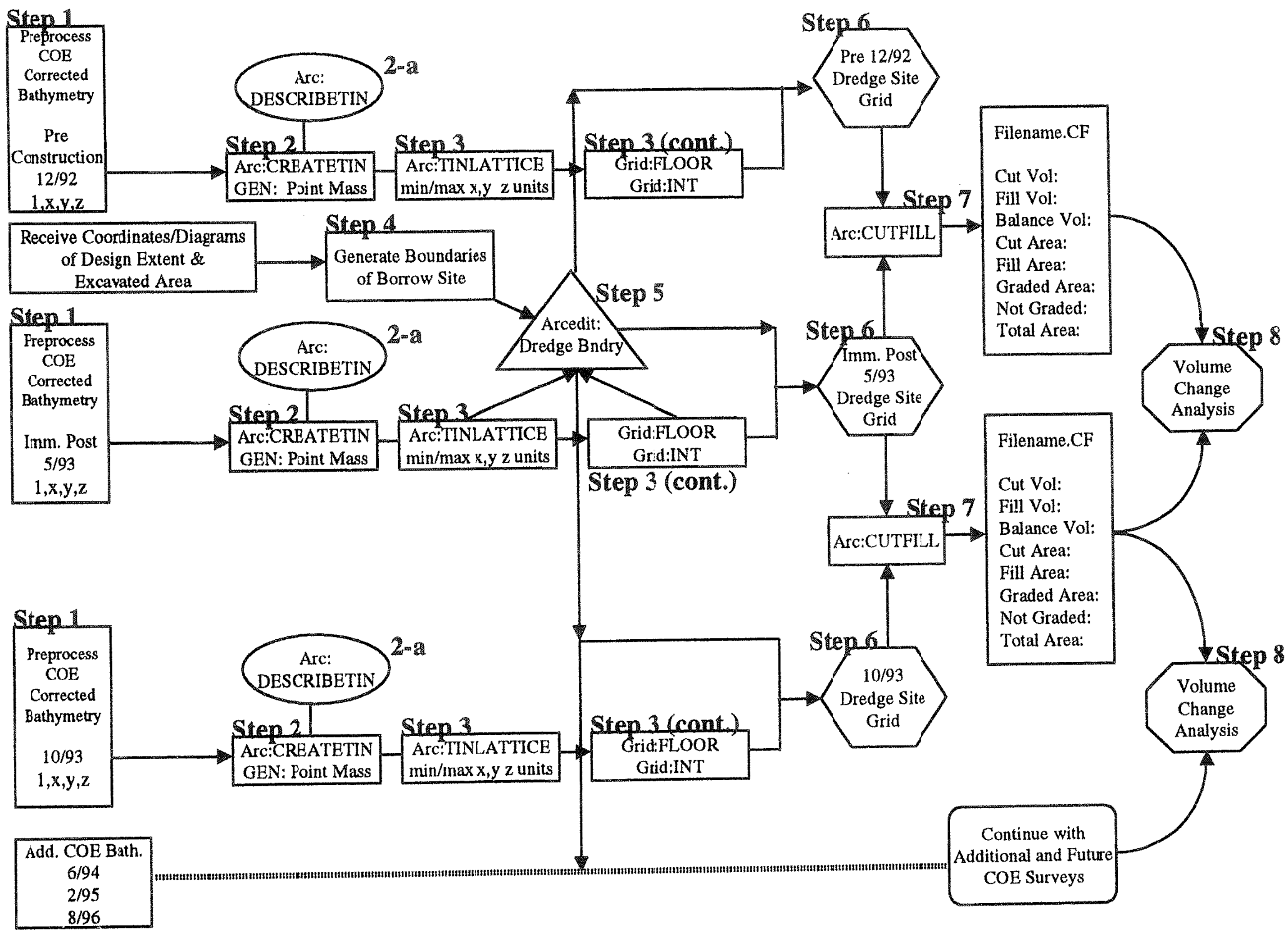

Figure 7. GIS Processing flowchart of the volume change analysis for the Folly River borrow site.

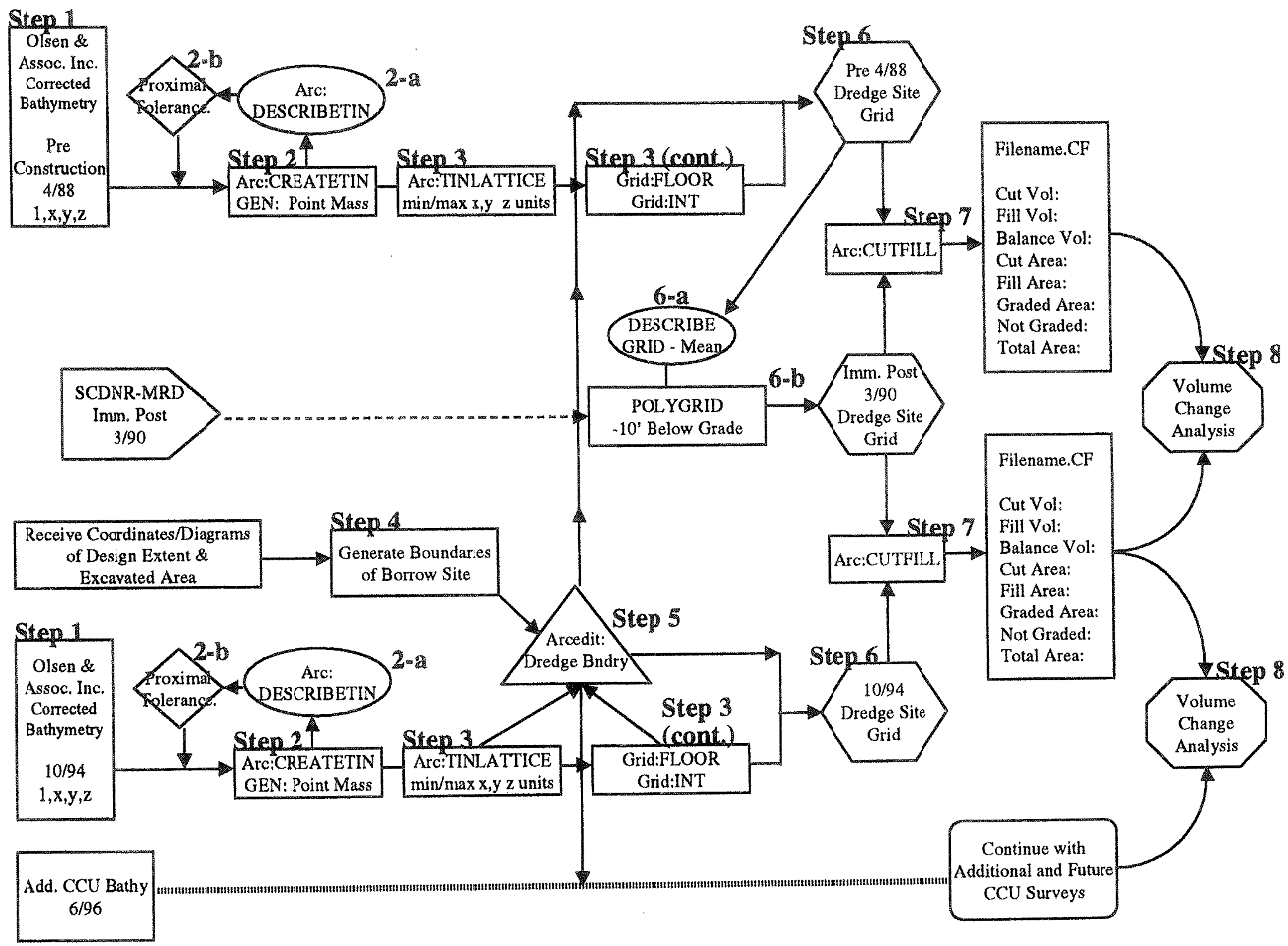

Figure 8. GIS Processing flowchart of the volume change analysis for the Joiner Bank (Hilton Head Island) borrow site.

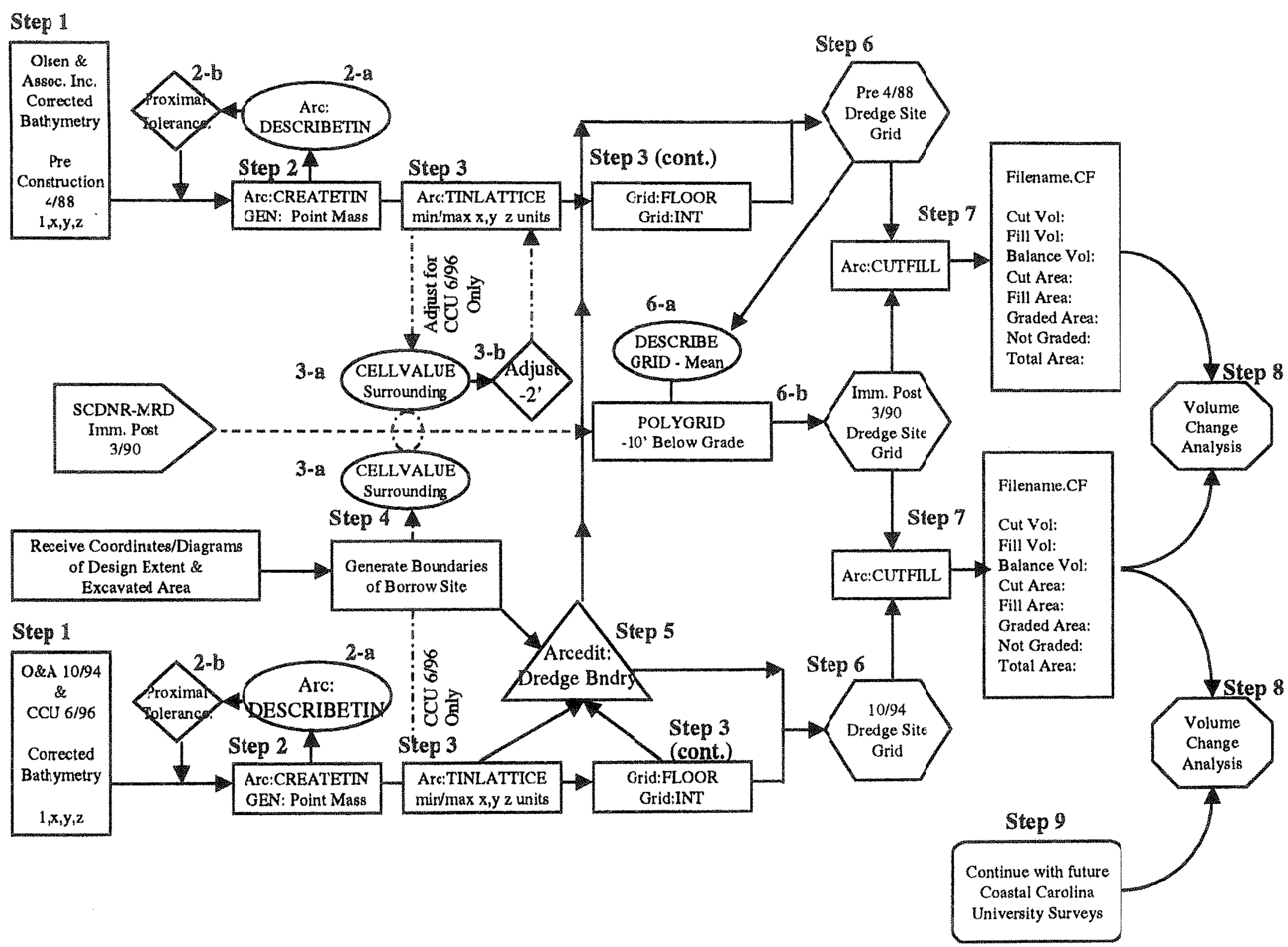

Figure 9. GIS processing flowchart of volume change analyses for the Gaskin Banks (Hilton Head Island) borrow site.

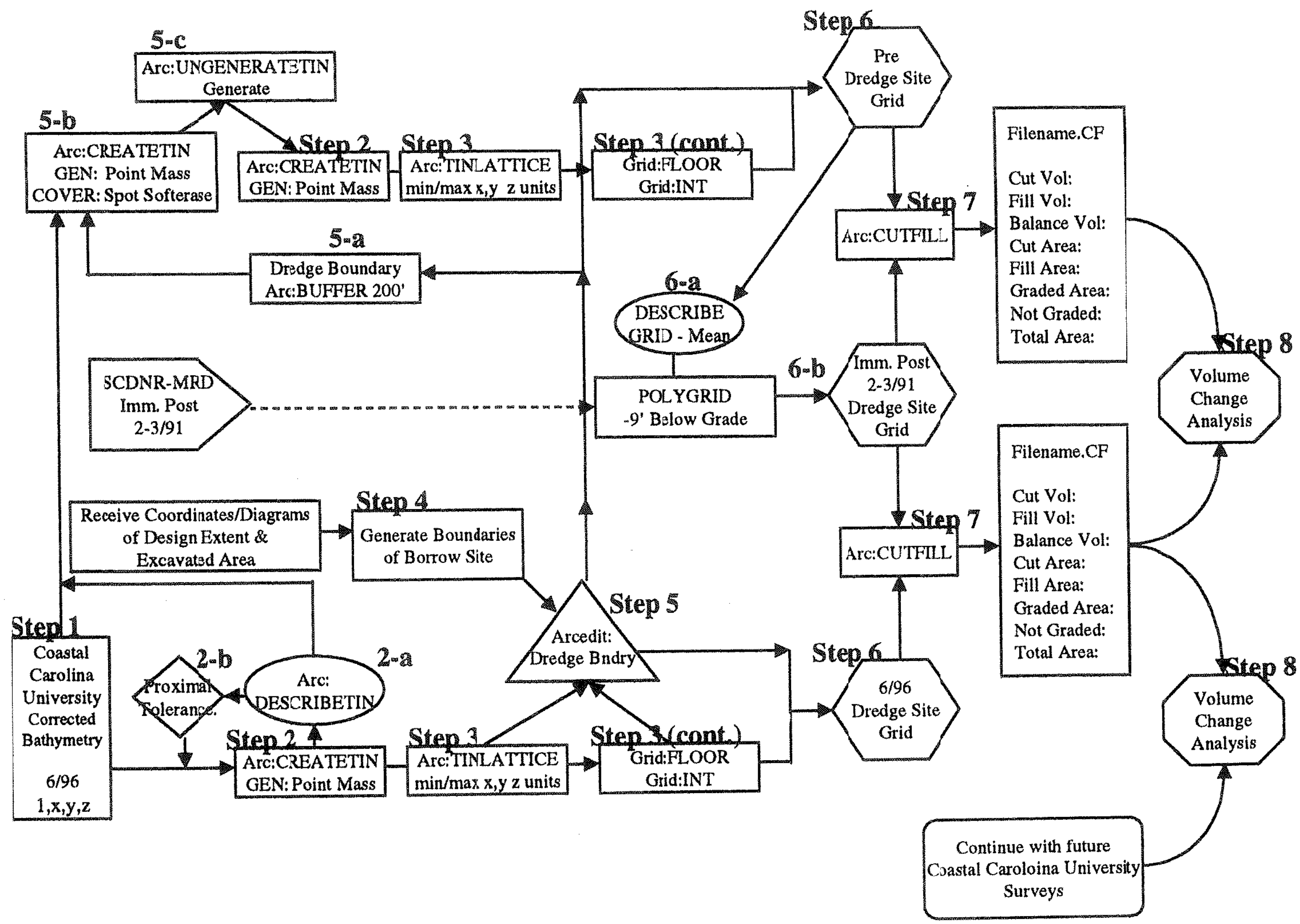

Figure 10. GIS Processing flowchart of the volume change analysis for the Hunting Island borrow site.

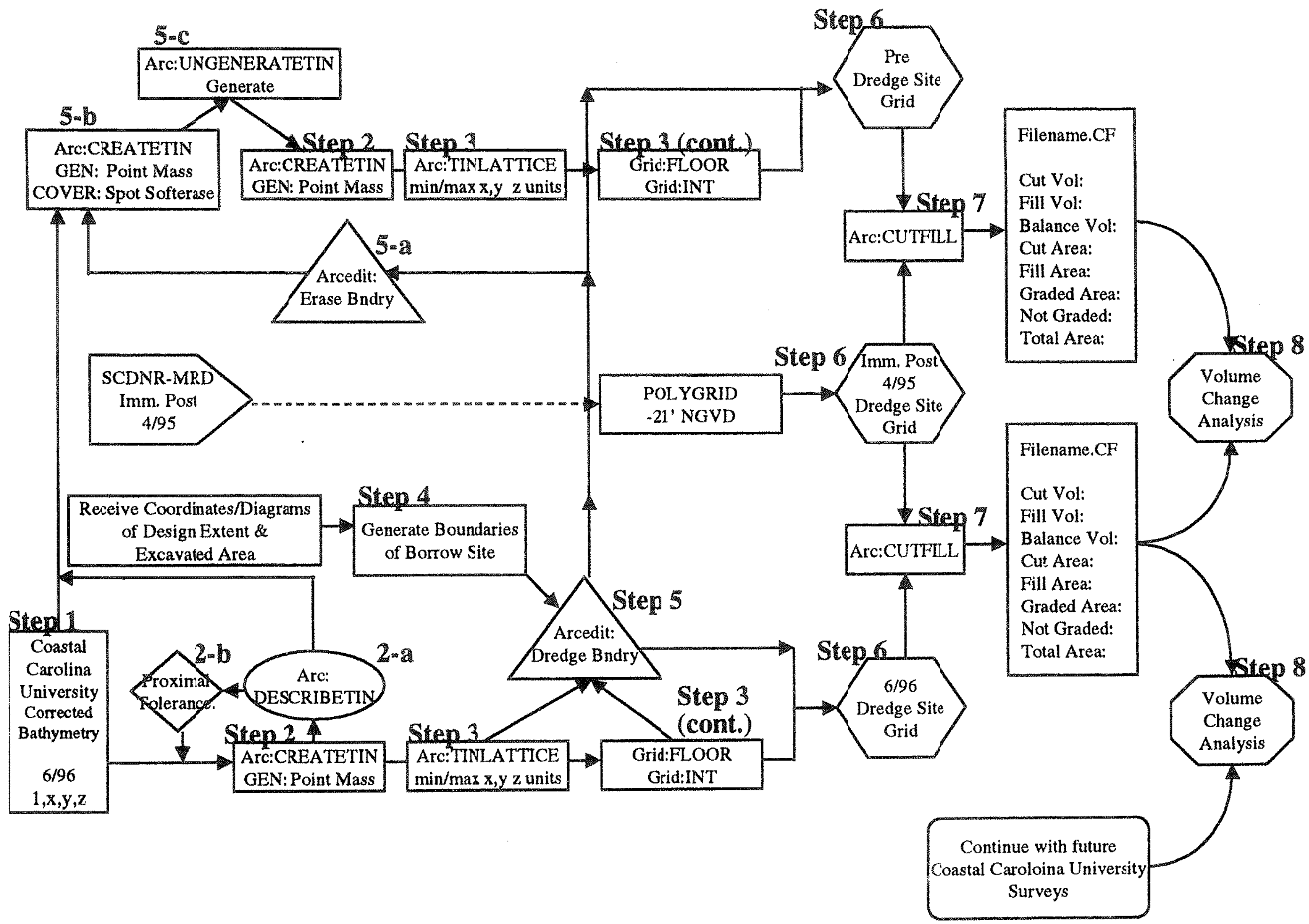

Figure 11. GIS Processing flowchart of the volume change analysis for the Edisto Island borrow site.

USACOE. These boundaries were then overlaid on a linearly stretched gray-scale image of the immediate post-construction surface GRID [STEP 5]. Because the immediate post-construction bathymetry showed that areas had been excavated outside the proposed site boundary, the boundary was edited to more accurately reflect the actual area dredged. A new dredge site surface GRID was then created that delineated the area inside the excavation boundary [STEP 6] since we were only concerned with the change in volume (i.e. sediment recovery) within that area.

The above steps were followed to create bottom surfaces for each subsequent survey period. Once the surfaces were created, a <CUTFILL> command was employed [STEP 7] to summarize changes in site volume that resulted from sediment deposition during the periods in between each survey period. Summary output from the CUTFILL operation included the volume of cut, volume of fill, the balance volume (volume cut + volume of fill), the total area cut, filled, graded, not graded, and total area of the site used in the analysis. Analysis of changes between the pre-construction surface and immediate post-construction surface gave us the initial volume of sediment removed during beach renourishment efforts. This estimate was compared to the volume reported to have been dredged by the USACOE. Subsequent surveys were used to compute changes in sediment deposition [STEP 8].

Gaskin and Joiner Bank Borrow Sites

The processing method used for these borrow areas was similar to that described for the Folly River borrow area with the following exceptions.

- When developing the mass points [STEP 2] an excessive amount of input data created numerical processing errors in developing the TIN. Therefore, the TIN was recreated by culling out soundings that fell within a specified distance (1/8 of the average width between boat transects across each survey area) of other points.

- Since immediate post-dredge data were unavailable for either borrow site, 10 ft (3 m) was subtracted from the average depth that occurred within the pre-construction (1988) surface profile at each area based on information provided by Creed (1995). The resulting profile represented our best estimate of the immediate post-dredging conditions at each site.
- The boundary of the dredged holes were also edited, based on the 1994 survey (Creed, 1995), to correct for obvious horizontal positional inaccuracies.
- At the Gaskin Banks site, there was an obvious and uniform difference in the depth sounding data between the 1994 survey (Creed, 1995) and the Coastal Carolina University 1996 survey. Therefore, each survey was used independently to compute the sediment volume missing from the dredged area compared to the surrounding bottom profile provided by that survey effort. Specific protocols used for each survey period are given in Figures 8-9.
- Post construction profiles and volume change estimates generated by our GIS analyses were compared with reported estimates of the volume of material dredged from each site (Creed, 1995).

Hunting Island Borrow Site

The Hunting Island borrow site volume change analysis was also computed from the 1996 post-construction bathymetric survey conducted by CCU (Figure 10). To accomplish this, a pre-construction bottom surface profile was developed within the borrow site by interpolating the surface using the 1996 bottom bathymetry surrounding the hole. A buffer of 200 feet was applied to the dredge boundary to mask the notable amount of slumping that had occurred around the Hunting Island borrow site. Volume estimates based on the depth and size of the hole were compared with the volume of sediments that were reported to have been dredged (CSE-Baird: T. Kana, pers. comm.).

Edisto Island Borrow Site

The Edisto Island borrow site volume change analysis was computed from the 1996 post-construction bathymetric survey conducted by CCU using a similar approach to that described for Hunting Island (Figure 11), except that a 200 ft buffer was not applied to the boundary. By referencing diagrams and dredging depth estimates (-21 ft NGVD) reported by CSE-Baird (1996) a uniform and consistent construction profile was created. Volume estimates based on the depth and size of the hole created in STEP 5 were compared with the volume of sediments that were reported to have been dredged (CSE-Baird 1996).

Seabrook Island Borrow Site

Computations of bathymetric changes at the Seabrook Island site could not be completed due to the limited amount of information available for the area, combined with the presence of a pre-existing shore-parallel channel adjacent to the borrow area (see Results and Discussion section). Bathymetry data from the CMWS survey completed in 1996 were compiled and evaluated using the GIS to determine whether evidence of a dredged hole was still present.

Surficial Sediment Survey:

The amount of pre- and post-dredging characterization of the South Carolina borrow sites has been limited. The Hilton Head and Folly Island borrow areas were monitored extensively on one or more dates prior to dredging and then at quarterly intervals for one year after dredging (Van Dolah et al., 1992, 1994). The Hunting Island and Edisto Island borrow areas received more limited surveys on one or two sampling dates subsequent to the dredging activitiy (Creed, 1995; CSE-Baird, 1996a, 1996b), and the Seabrook Island site was not monitored at all. Since there was no information on the long-term changes in sediment composition at most of these sites, surficial sediment samples and a more limited number of deeper vibracore samples were collected in each study area by the CMWS in 1996 during the bathymetric surveys. Textural parameters measured in these samples were: percent gravel/sand/silt/clay, moment measurements (mean, sorting, skewness and kurtosis) for the bulk and non-carbonate fraction and the percent carbonate in the bulk sample.

Field Sampling Methods

Sample locations were randomized to provide a general representation of the surficial sediment characteristics in each borrow area. The surficial sediment samples were collected using a 0.04m^2 Young grab. Vibracores were collected using a standard gas-powered vibracore system with three-inch diameter aluminum pipes from a small boat. A Trimble Pro XL linked to a Starlink Differential Global Position System (DGPS) was used for navigation, with data processed using HYPACK survey software.

The number of samples collected at each site varied with the area of the site and are provided in Table 1. Specific sample locations are provided in the "Results and Discussion" section for each area.

Table 1. Listing of surficial sediment and vibracore samples collected from each of the borrow areas in 1996.

Borrow Site	Sediment Samples	Vibracores
Hunting Island	13	
Edisto Island	6	3 (+2 on adj. shoals)
Seabrook Island	7	
Hilton Head -Joiner Banks	10	
Hilton Head-Gaskin Banks	11	2

Laboratory and Data Analysis Methods:

Surficial sediment samples and vibracores were returned to CCU for processing and analysis. Sediment textural parameters for the bulk samples (percent gravel, sand, silt and clay , sample mean grain size, sorting, skewness and kurtosis) were determined by standard Rotap sieve analysis techniques. The percent carbonate was determined by dissolution of the carbonate (shell) fraction using a dilute acid (HCl). Sediment textural parameters were also determined for the non-carbonate fraction.

Vibracores were split, photographed and visually described for sediment texture, color, sedimentary structures and the nature of transitions and contacts.

RESULTS AND DISCUSSION

Folly River Borrow Area:

Bathymetric Surveys:

Comparison of the pre-construction bathymetry with the immediate post-construction bathymetry survey (Figures 12-13) revealed that some areas outside the proposed boundary of the site had been excavated. When the boundary was modified to include these areas, the total volume of material we estimated to have been removed from the site based on the two surveys was approximately 2.9 million cubic yards (Table 2). This estimate was slightly lower than the 3.1 million cubic yards estimated by the USACOE to have been dredged from the area. There are three possible explanations for the observed difference:

- Sediment deposition may have occurred in some portions of the borrow area between the two surveys, particularly those areas that had been initially dredged early in the project.
- We may have underestimated the actual boundary of the excavated site in areas where the boundary was not clearly defined by changes in bathymetry.
- The USACOE estimate may be inaccurate.

Regardless of the reason, the volume of sediment that could not be accounted for (approximately 225,000 cu yds) was less than 8% of the total volume removed using either estimate.

By October 1993, six months after dredging was completed in the area, approximately 397,000 cu yds of material had accumulated in the borrow site (Table 2), with most of the deposition occurring approximately midway along the main axis of the borrow site (Figure 14). This area was adjacent to a large shoal located at the southern end of Folly Island that was exposed to ocean wave action. Wave action and flood tidal currents across the shoal probably moved the majority of the sediments that were filling

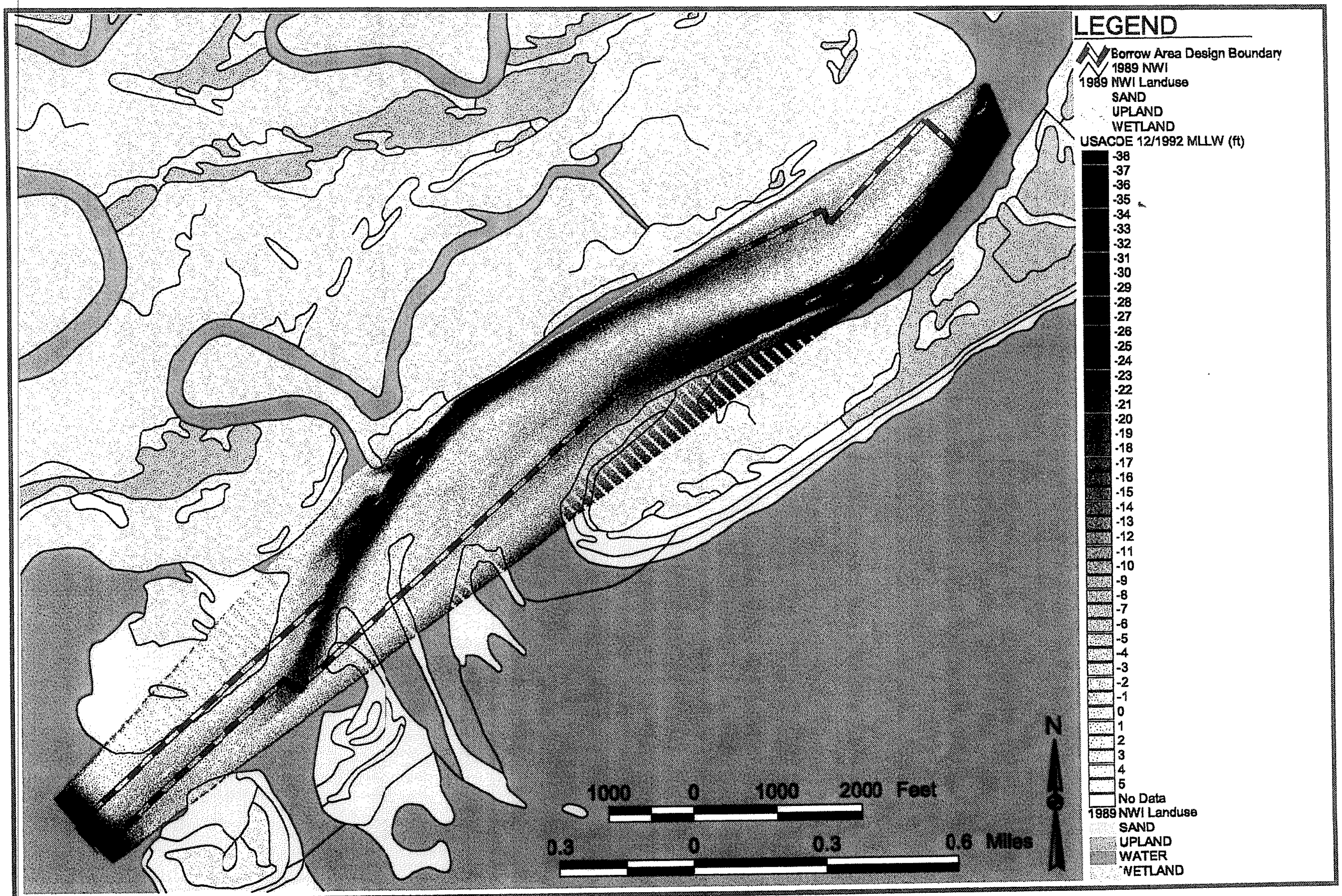

Figure 12. Folly River borrow site with bathymetric data from the USACOE pre-construction survey (12/92).

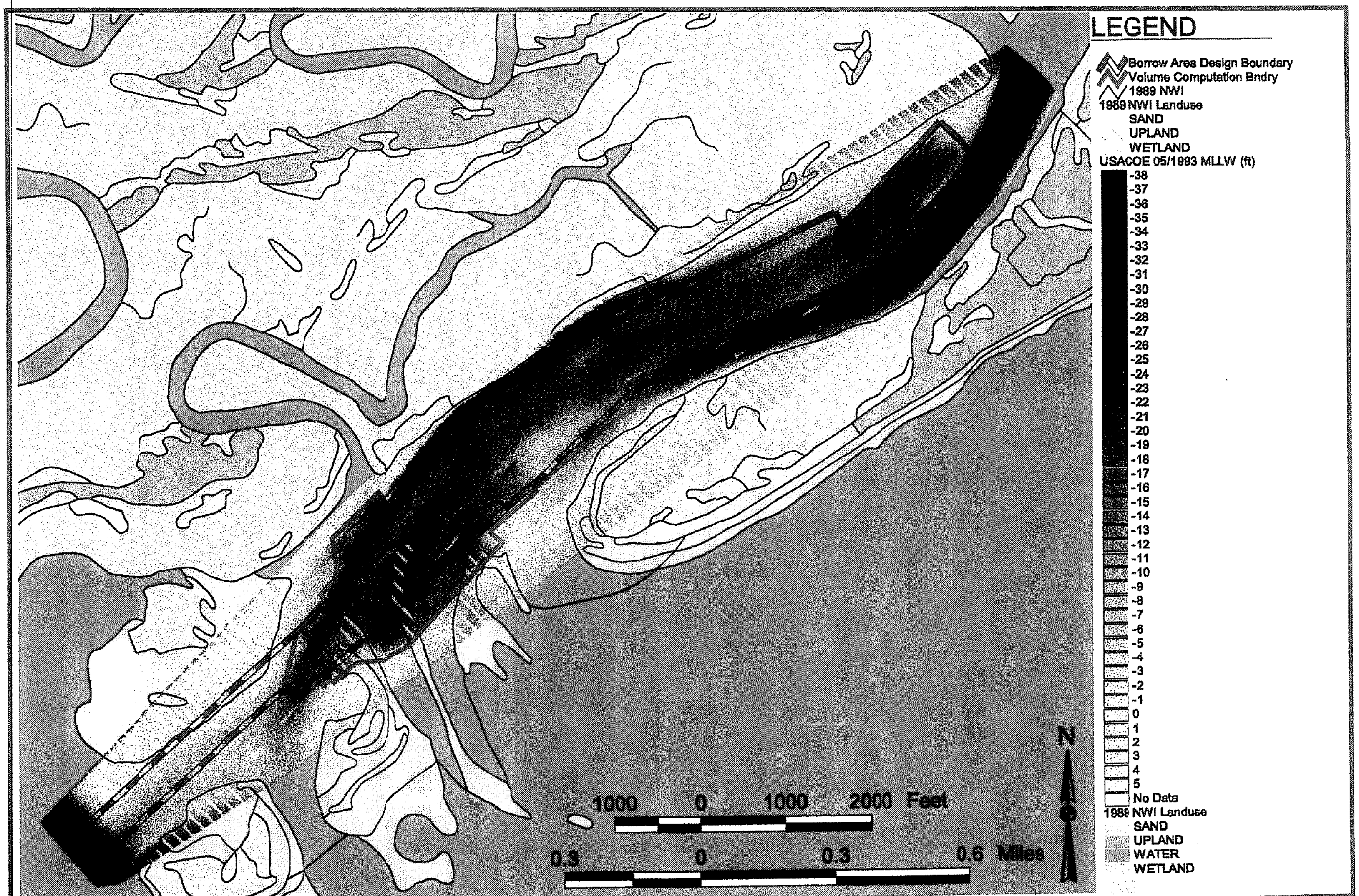

Figure 13. Folly River borrow site with bathymetric data from the USACOE post-construction survey (5/93).

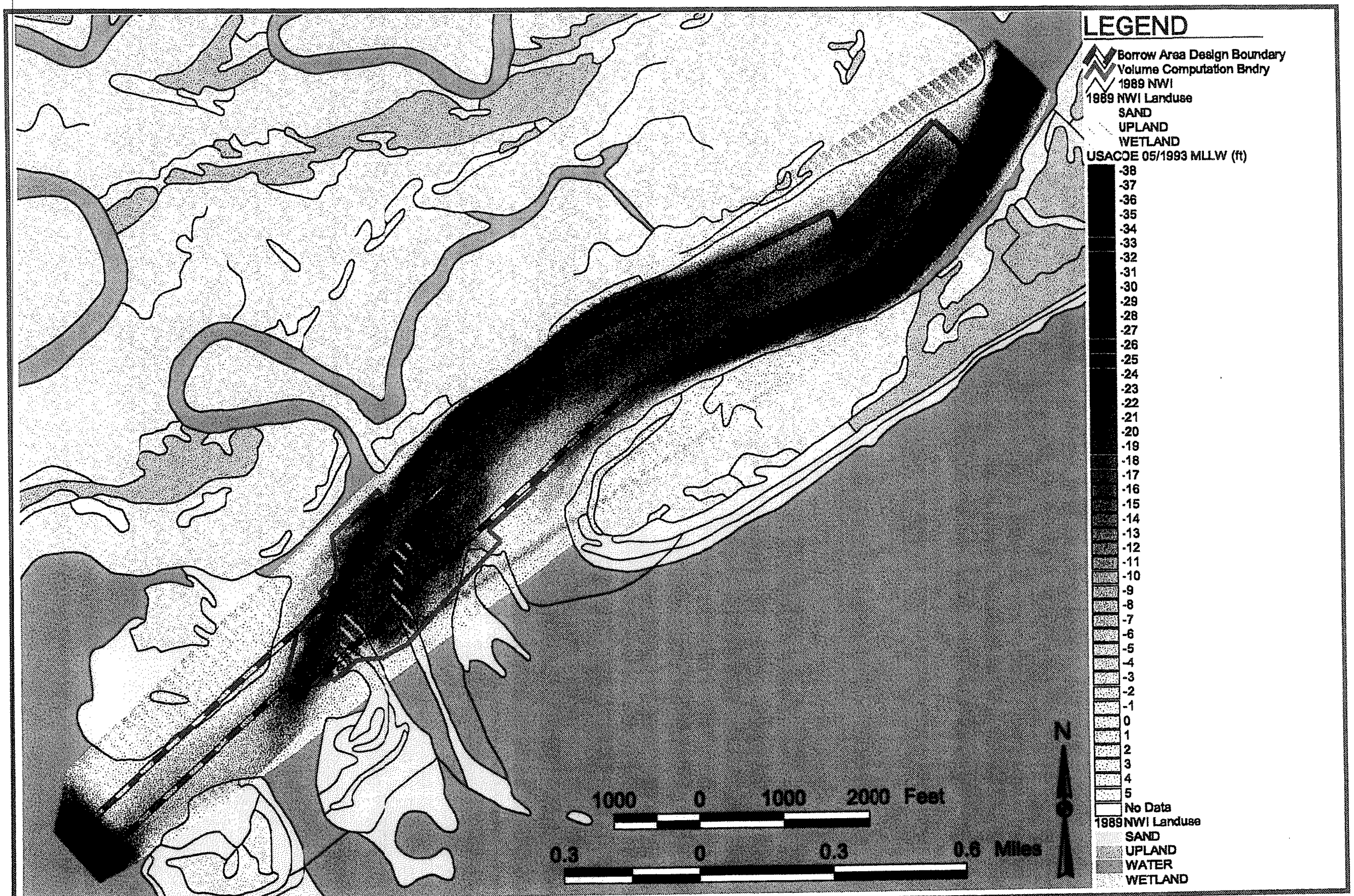

Figure 14. Folly River borrow site with bathymetric data from the USACOE post-construction survey (10/93).

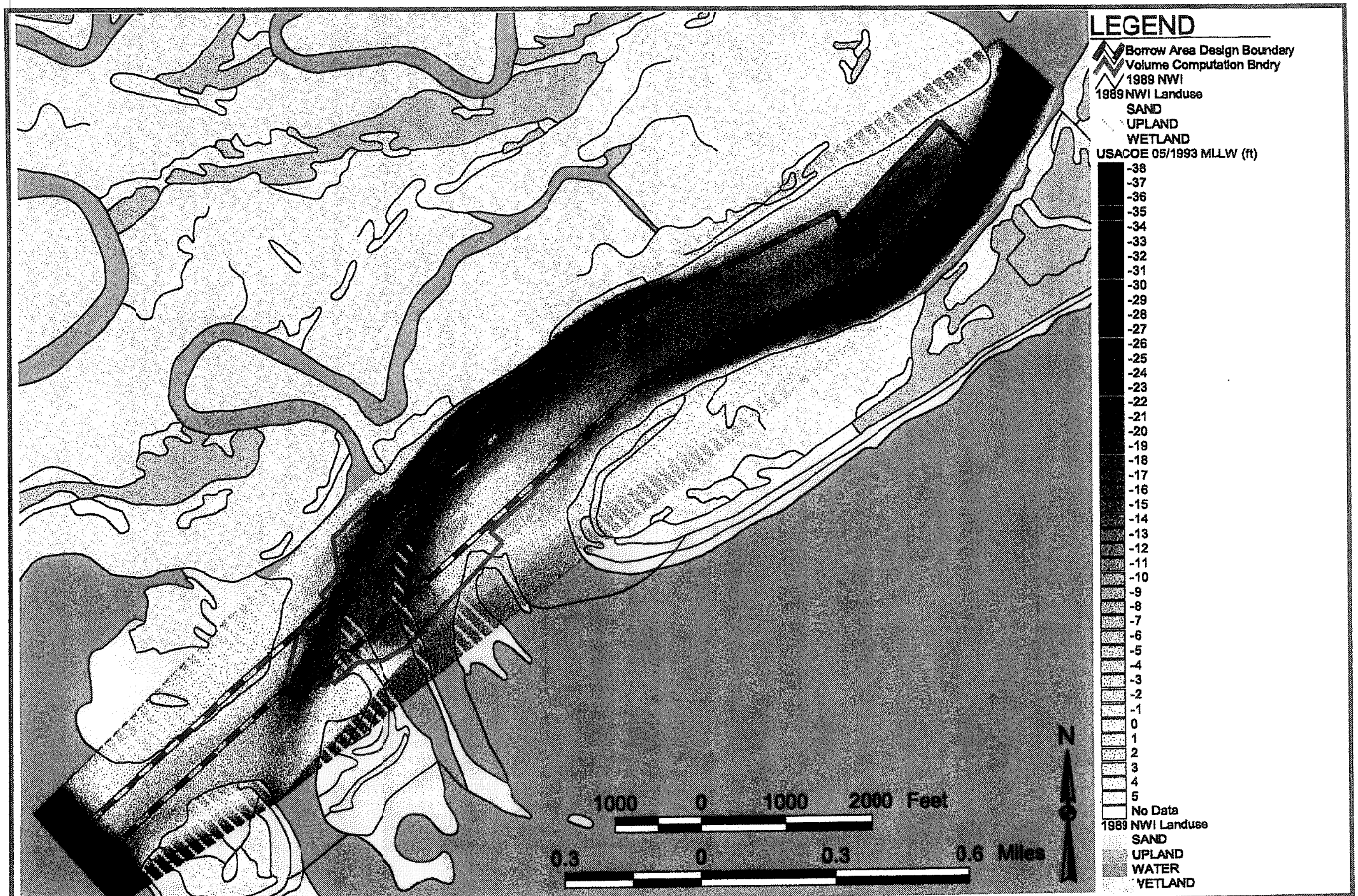

Figure 15. Folly River borrow site with bathymetric data from the USACOE post-construction survey (6/94).

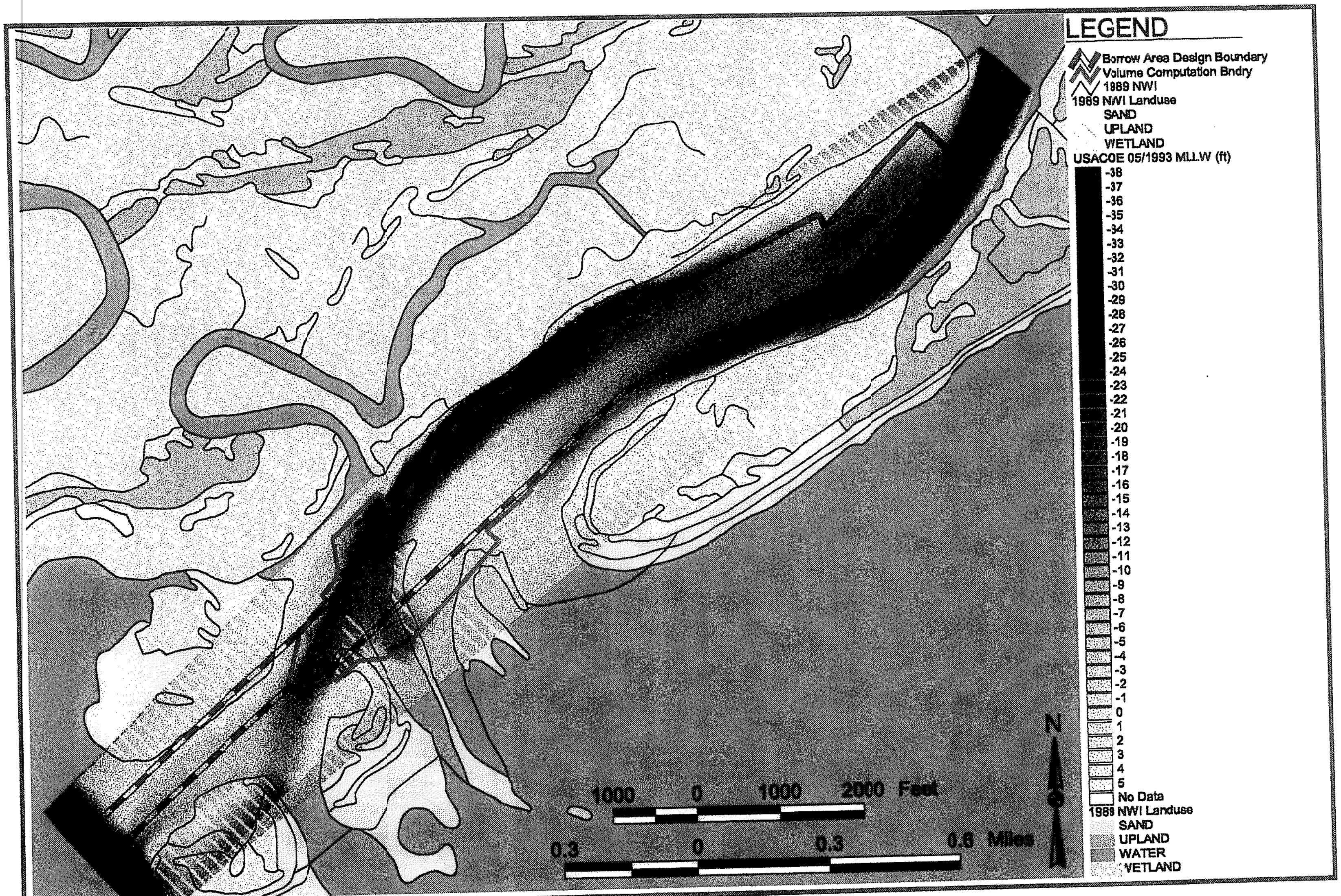

Figure 16. Folly River borrow site with bathymetric data from the USACOE post-construction survey (2/95).

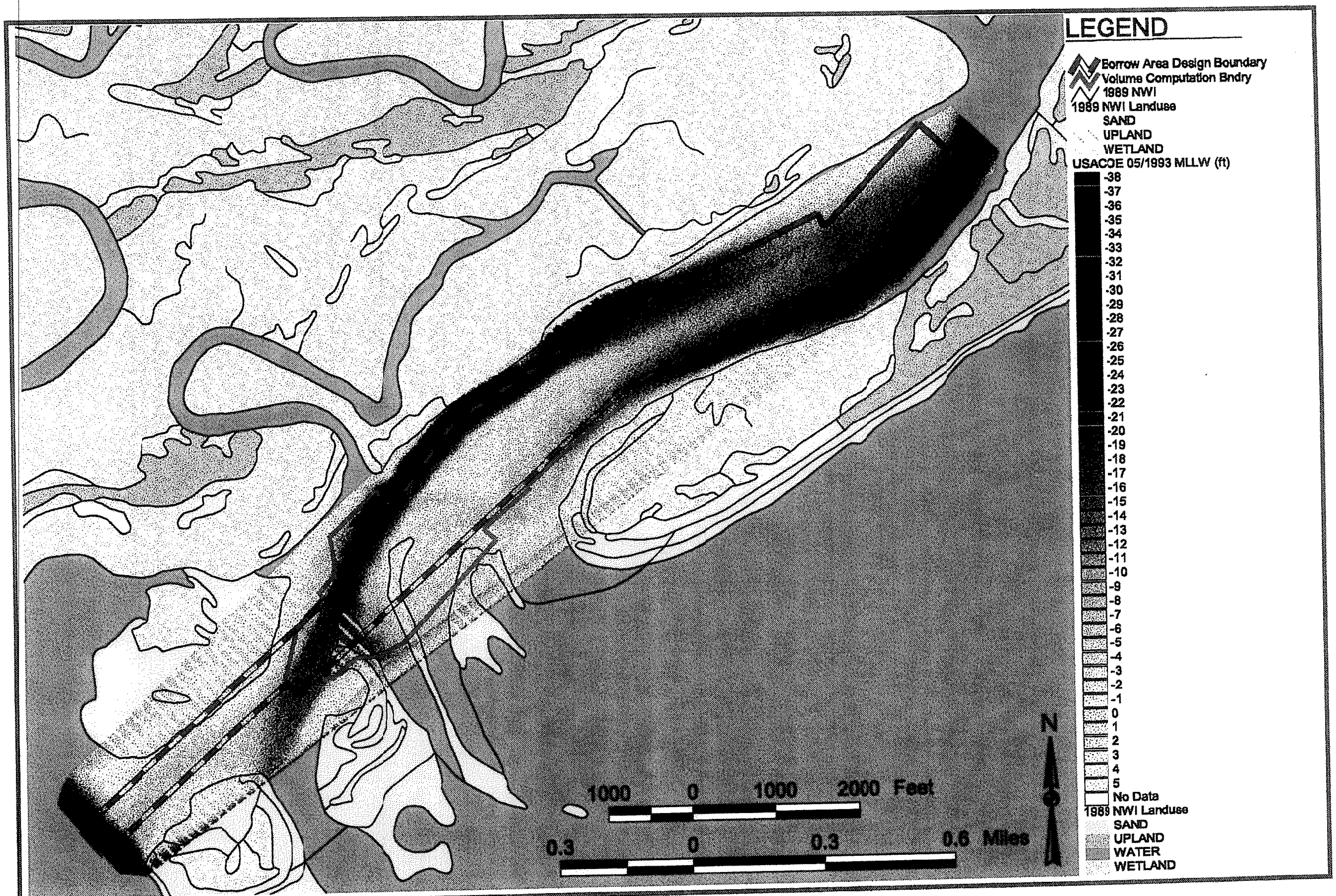

Figure 17. Folly River borrow site with bathymetric data from the USACOE post-construction survey (8/96).

Table 2. Volume change analyses measuring sediment deposition within the inshore Folly River Borrow Site following dredging activities in May 1993. All surveys were conducted by the US Army Corps of Engineers. Shaded area represents natural changes in the borrow area after dredging was completed.

	Time Periods Between Bathymetric Surveys					
	Dec 92-IP*	IP-Oct 93	Oct 93-June 94	June 94-Feb 95	Feb 95-Aug 96	Totals
Time Period between Surveys (Years)		0.42	0.67	0.67	1.5	3.26
Volume Deposited (cubic yards)	81,555	483,279	511,658	668,549	792,807	2,456,293
Volume Lost (cubic yards)	-2,956,577	-86,396	-140,981	-243,382	-265,215	-735,974
Net Vol Change (calculated)	-2,875,022**	396,883	370,677	425,167	527,592	1,720,319
Volume Removed (USACOE estimated)	3,100,000***					
% of Orig Loss Replaced during Period		14%	13%	15%	18%	60%

* IP = Immediate Post Survey conducted in May 1993 immediately after dredging was finished.
** Represents calculated volume of removed sediment.
*** Represents estimated volume of sediment placed on the beach (Gayes 1997).

Volume of Sediment Still Missing (yds3)	1,154,703
Avg % Orig Loss Replaced/Year:	18%
Estimated Total Years to Replace:	5.5

At this rate, the borrow area should be filled by November, 1998.

the borrow area. Deposits of muddy sediments were also observed to be moving into the borrow area by Van Dolah et al. (1994). These sediments were probably originating from the Stono River and tidal creeks draining the marshes adjacent to the borrow site. However, deposition from these sources did not appear to be as great as the deposition originating from the ocean-side shoal noted above based on the bathymetric surveys (Figures 12 – 17).

By the summer of 1994 approximately 27% of the 2.9 million cubic yards of sediment we estimated to have been removed from the site had been replaced by newly accumulated sediments, and by August of 1996 (the last survey) 60% of the sediments had been replaced (Table 2). This represented an average annual refilling rate of 18%, which would result in complete refilling of the area within 5.5 years if this rate of sediment accumulation was maintained. The primary area of deposition appeared to be in the middle portion of the borrow site, just west of the end of Folly Island. Material in the borrow site appeared to be moving primarily to the east, with more limited deposition observed in the western half of the site (Figures 15-17). A distinct channel was present on the northern side of the borrow site as well. This channel was similar to the channel that existed prior to dredging, except at the western end where it was larger than previously observed.

No later surveys were available to confirm the estimated time it would take for the area to completely refill to pre-dredge conditions, and portions of the Folly River channel within the study area were re-dredged in 1996 for routine channel maintenance. Thus, continued monitoring efforts would have been difficult to interpret even if later surveys had been conducted.

Although much of the Folly River borrow area appeared to have refilled rapidly compared to some of the other borrow sites evaluated (see later sections), it is interesting to note that there were substantial modifications in the configuration of the Folly River channel compared to pre-dredge conditions. This was particularly evident in the area near Bird Key, which was an emergent shoal adjacent to the mouth of the Stono River that supported one of the largest brown pelican rookeries on the east. Although no significant dredging had occurred in the Folly River behind Bird Key, creation of a deeper and wider river channel to the east of this area resulted in the expansion of an inlet channel to the ocean. This change, combined with wave erosion on the ocean-side of Bird Key, severely eroded the island during the survey period (Figures12-17). By the end of the survey, the island no longer existed and remediation efforts were initiated to create another area that would be suitable for bird nesting on the shoal between the area where Bird Key had been and Folly Island. The loss of Bird Key may have been the result of several factors, but it is clear that modification of inlet shoals and channels can have significant unanticipated impacts.

Surficial Sediment Surveys:

Samples were not collected in the Folly River borrow site as part of this study since this area was not surveyed by the CMWS. However, some post-dredging data are available from a monitoring study conducted by the S.C. Department of Natural Resources (Van Dolah et al., 1994). During that study, approximately 120 surficial grab samples were collected in three reaches of the borrow site prior to dredging as part of an extensive assessment of benthic resources. Those samples indicated that fine sand was the dominant component (generally > 85%). Following dredging, surficial sediments had a greater silt-clay content, which increased over time during the 1-year post dredge assessment period. Within nine months after dredging (November, 1993), the average silt-clay content in the samples had exceeded 40% in the western portion of the borrow site. Additionally, 9 of the 10 samples collected from that zone had greater than 10% silt-clay content, indicating widespread distribution of muddy material (Van Dolah *et al.*, 1994). The increase in muddy sediments was attributed to a combination of the inshore location and close proximity to extensive marsh habitat which drained into the borrow area through a large creek. The silt-clay content of surficial sediments in the portion of the borrow site behind Folly Island also increased compared to pre-dredge conditions, and approached 10% by the end of the study (Van Dolah *et al.*, 1994). Although this monitoring project was not continued past the 1-yr assessment period, our analysis of the bathymetry suggested that subsequent ingress of sediment was largely sandy material moving from the shoals located on the ocean side of the borrow site. Whether these sands displaced the muddy material or capped those sediments is unknown since vibracores were not taken in this area, but there is a possibility that some of the borrow site may now contain material that is unsuitable for future beach nourishment. Detailed coring studies should be conducted if this area were to be reused as a borrow site. However, the data provided by the SCDNR suggest that other sites located offshore may be more suitable as borrow areas since they would be less likely to accumulate muddy sediments. Since the Folly River must be dredged periodically for channel maintenance, some portion of that material may be useful for nourishment operations if muddy sediments can be avoided.

Hilton Head Borrow Sites:

Bathymetric Surveys:

The 1988 pre-dredge survey of the Joiner and Gaskin Banks shoals (Figures 18,21) indicated that there were no major natural depressions in bottom topography within the borrow site boundaries as reported by Great Lakes Dock and Dredge Company (dashed line) or as defined by our best assessment of the actual area dredged (red line). At the eastern limits of the Joiner Bank shoal, a narrow channel was dredged from the natural channel bank of the Port Royal entrance channel in order for the dredge to gain access to the borrow site. Although it is unclear exactly where dredging began, errors in the boundary at this point would not have a major impact on volume estimates. Similarly, there was a natural deepening of the bottom topography to the north and west

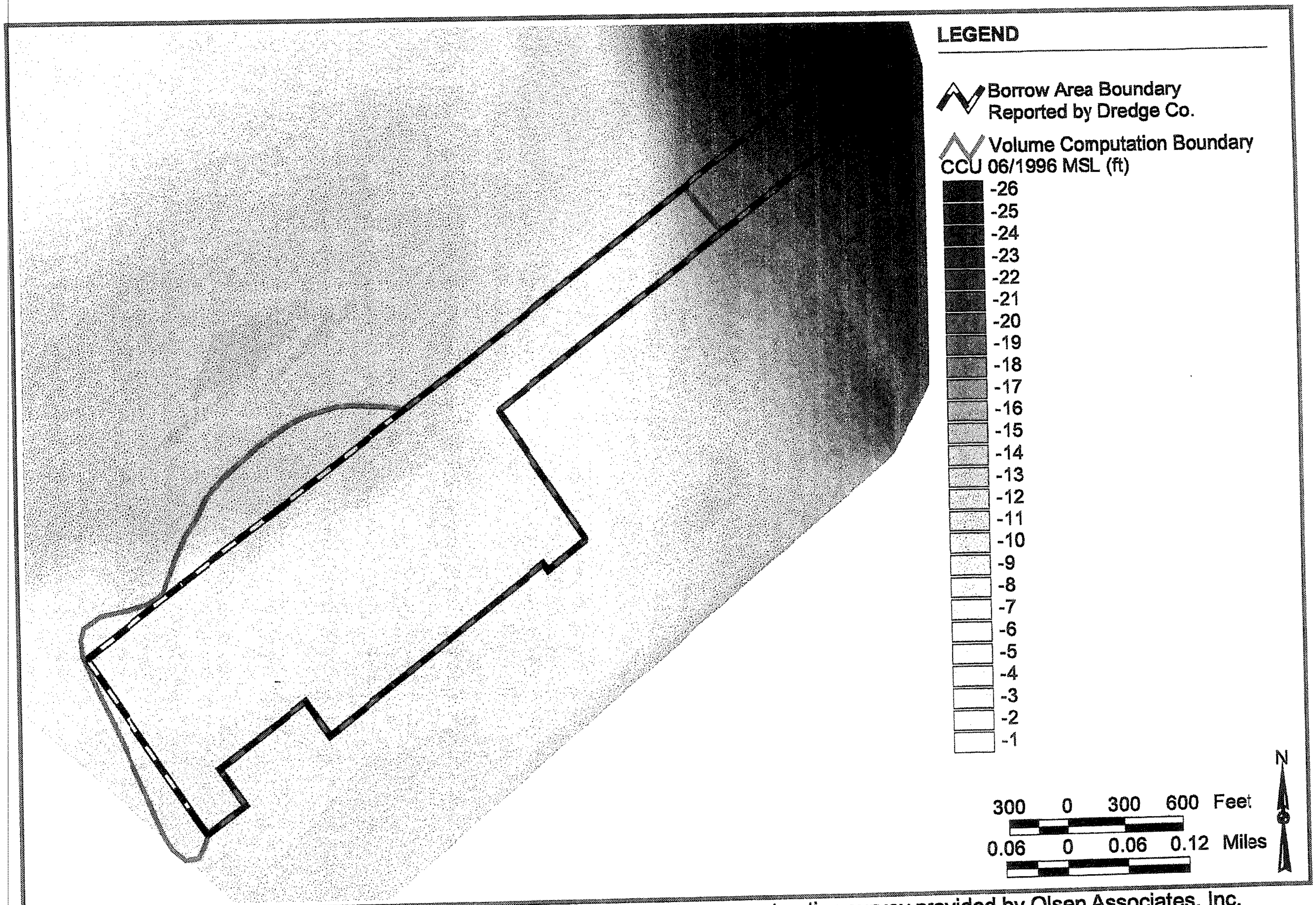

Figure 18. Joiner Bank borrow site with bathymetric data from the 1988 pre-construction survey provided by Olsen Associates, Inc.

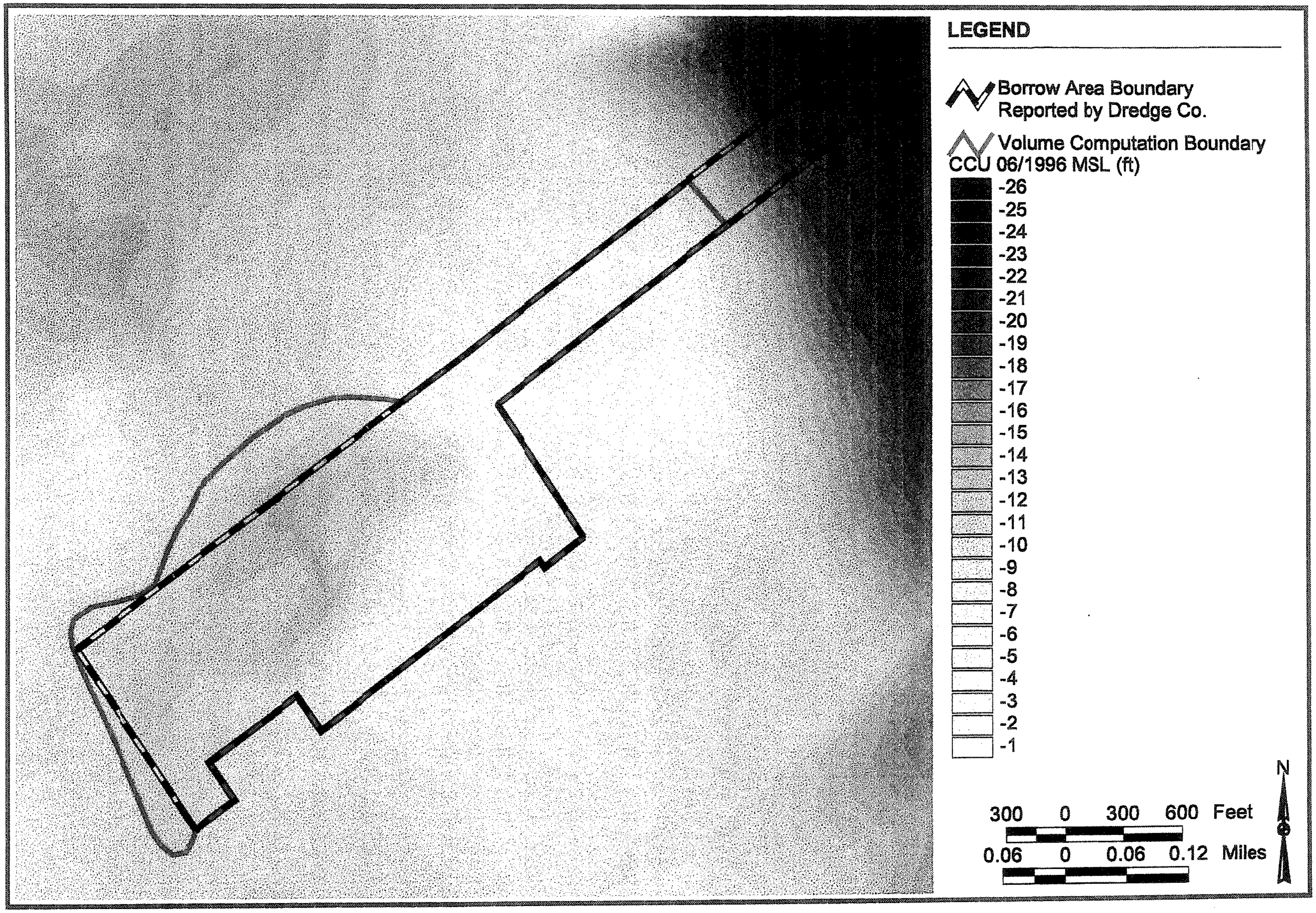

Figure 19. Joiner Bank borrow site with bathymetric data from the 1994 post-construction survey conducted by Coastal Carolina University.

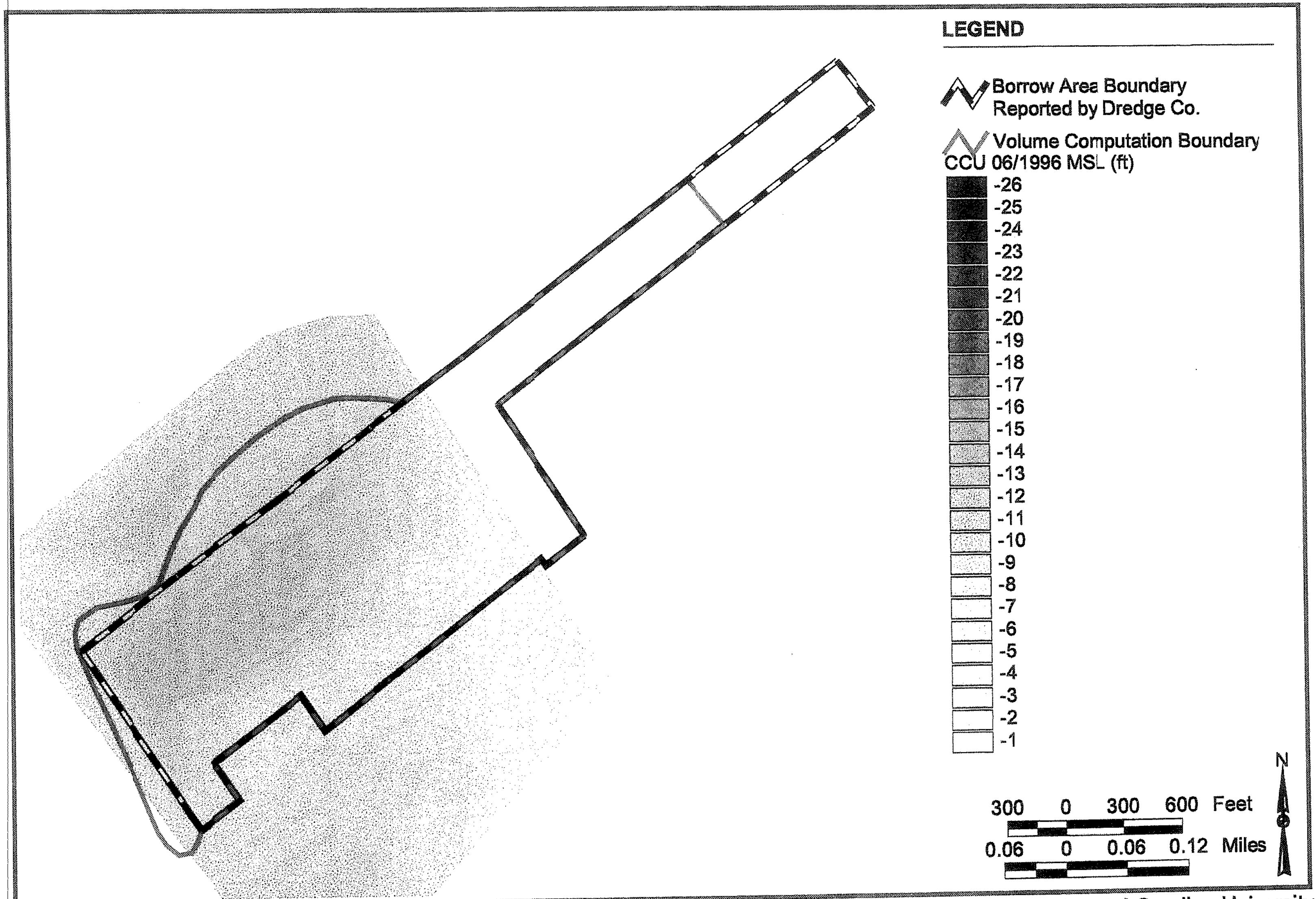

Figure 20. Joiner Bank borrow site with bathymetric data from the 1996 post-construction survey conducted by Coastal Carolina University.

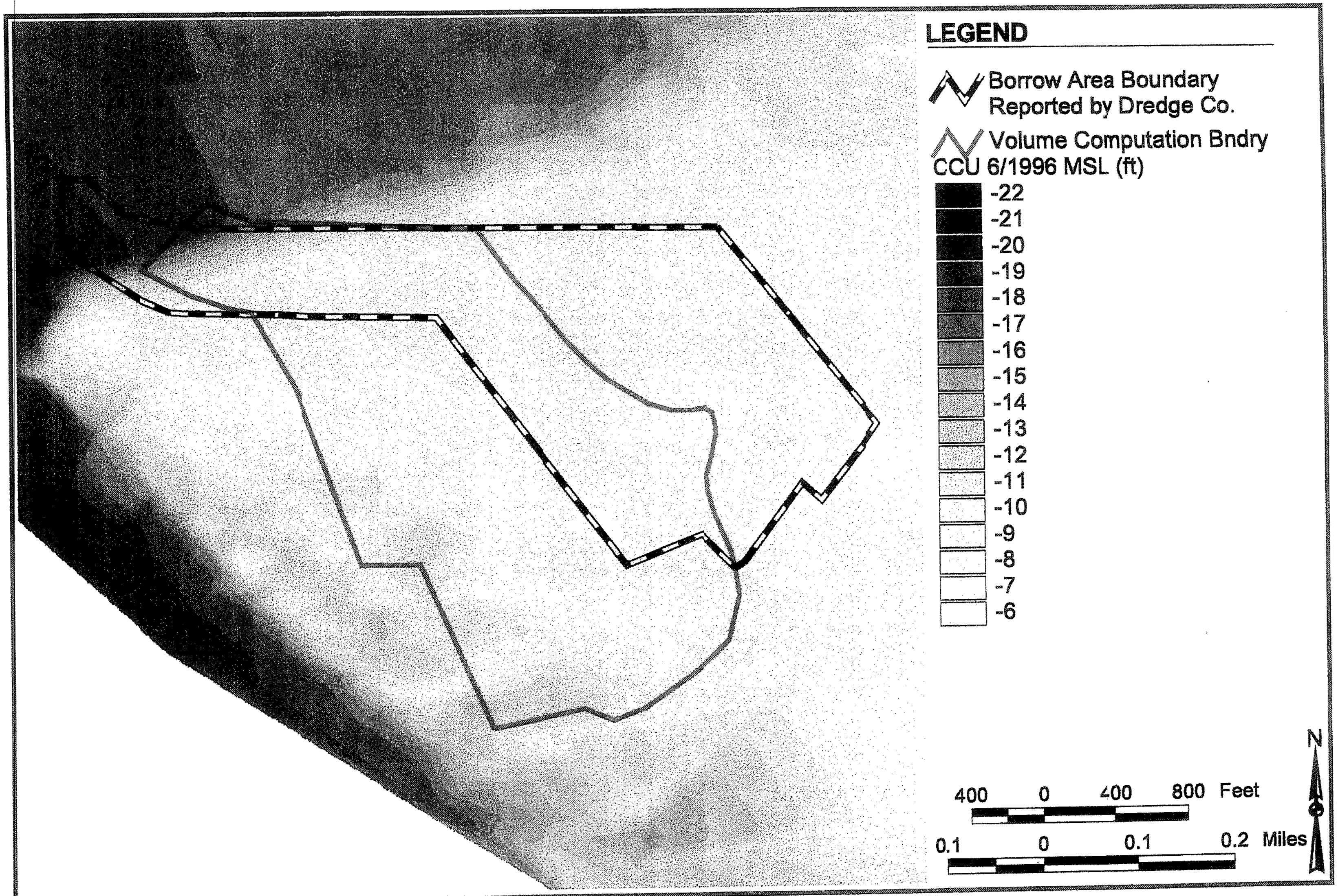

Figure 21. Gaskin Banks borrow site with bathymetric data from the 1988 pre-construction survey provided by Olsen Associates, Inc.

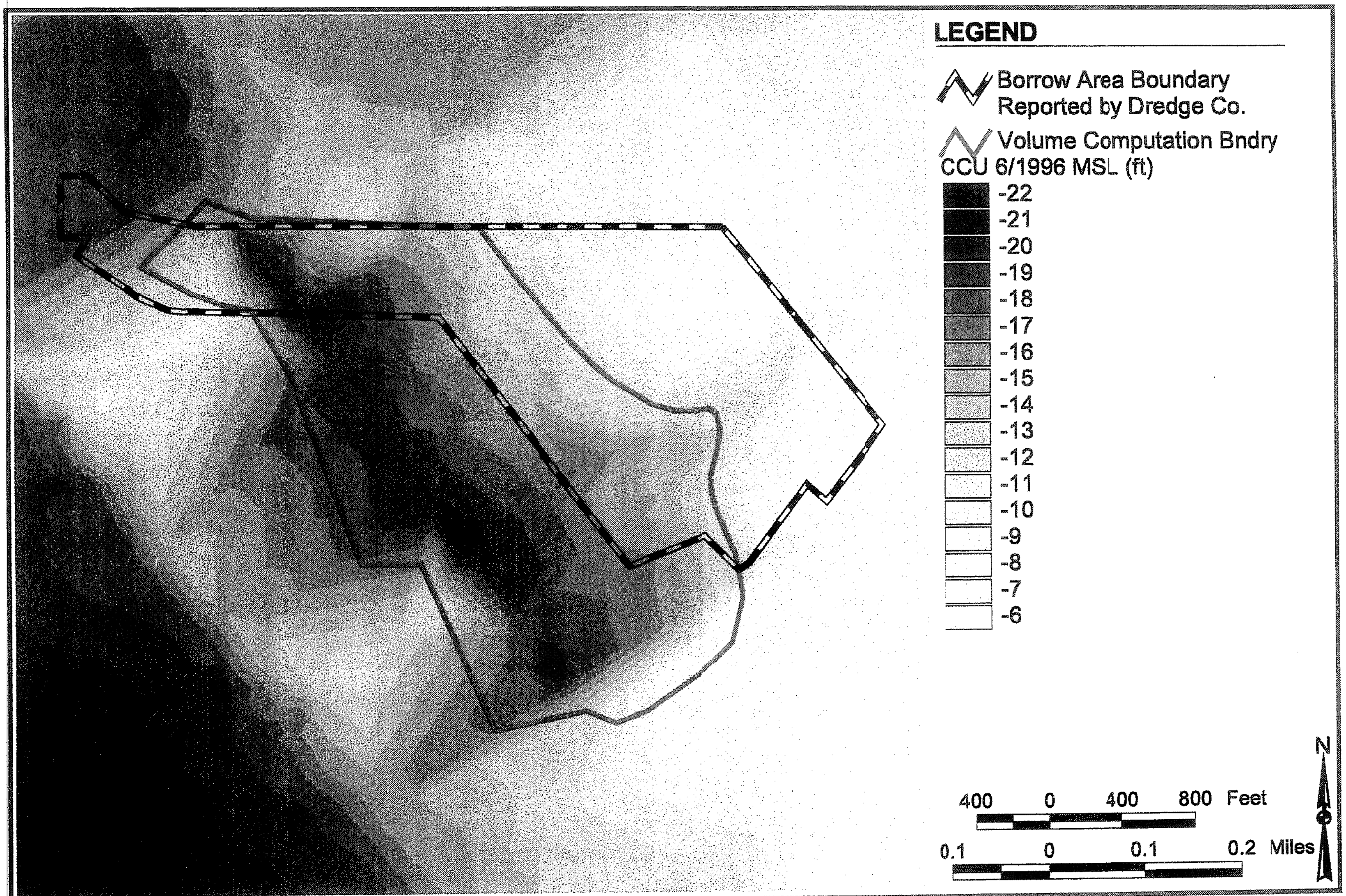

Figure 22. Gaskin Banks borrow site with bathymetric data from the 1994 post construction survey provided by Olsen Associates, Inc.

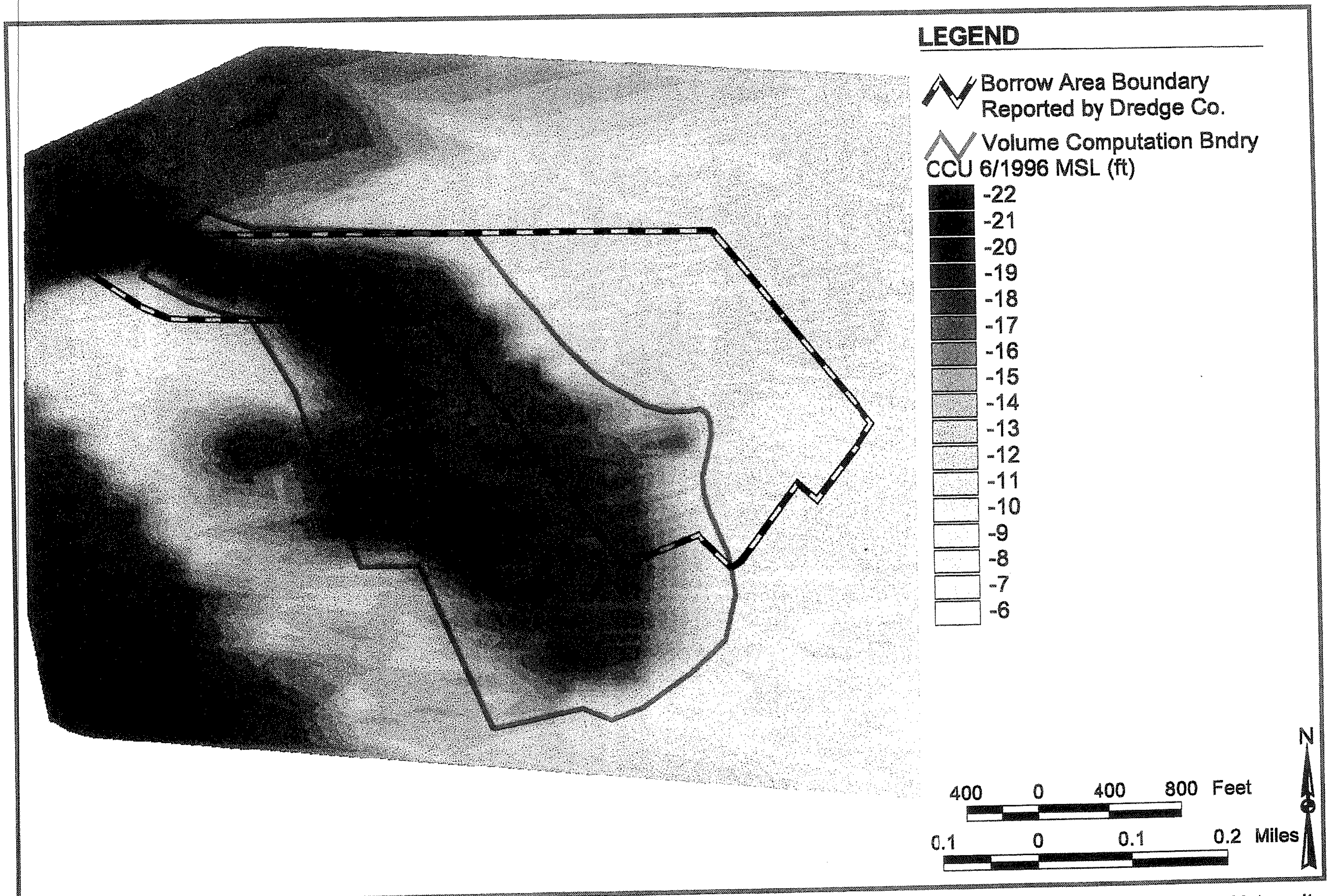

Figure 23. Gaskin Banks borrow site with bathymetric data from the 1996 post construction survey conducted by Coastal Carolina University.

Table 3. Volume change analyses measuring sediment deposition within the Joiner Bank borrow site following dredging termination in May 1990. The 1988 and 1994 surveys were conducted by Olsen Associates, Inc. The June 1996 survey was conducted by Coastal Carolina University. Shaded area represents natural changes in the borrow area after dredging was completed.

	Time Periods Between Bathymetric Surveys			
	Apr 88-IP*	IP-1994**	1994**-June 96	Totals
Time Period between Surveys (Years)		4	2	6
Volume Deposited (cubic yards)	0	1,109,137	33,423	1,142,560
Volume Lost (cubic yards)	-1,319,844	0	-49,614	-49,614
Net Vol Change (Calculated)	-1,319,844***	1,109,137	-16,191	1,092,946
Vol Removed (Olsen & Assoc. estimated)	1,446,586****			
% of Orig Loss Replaced during Period		84%	-1%	83%

* IP = Immediate Post dredging estimate for May 1990. A survey was not taken at this time. Therefore, volume changes were estimated using Great Lakes Dredge and Dock Company reports (daily perfomance records) and other reports from Olsen Associates, Inc. which provided the volume of sediment dredged and the depth to which dredging occurred. The depth of dredging (10 feet below grade) was verified by SCDNR and consistent across the bottom.

** Survey conducted between May and July 1994. Exact date unknown.

*** Represents calculated volume of removed sediment.

**** Represents estimated volume of sediment removed by dredging company (Olsen Associates, C. Creed, pers.comm.).

Volume of Sediment Still Missing (yds3)	226,898
Avg % Orig Loss Replaced/Year:	14%
Estimated Total Years to Replace:	7.1

At this rate, the borrow area should be filled by June, 1997.

Table 4. Volume change analyses measuring sediment deposition within the Gaskin Banks borrow site following dredging termination in August 1990. The 1988 and 1994 surveys were conducted by Olsen Associates, Inc. The June 1996 survey was conducted by Coastal Carolina University. Shaded area represents natural changes in the borrow area after dredging was completed.

	Time Periods Between Bathymetric Surveys			
	Apr 88-IP [a]	IP-1994 [b]	1994-June 96 [c] **IP-June 96** [d]	Totals
Time Period between Surveys (Years)		4 -	2 **6**	6 **6**
Volume Deposited (cubic yards)	0 **0**	807,814 -	30,566 **924,967**	838,380 **924,967**
Volume Lost (cubic yards)	-1,808,862 **-1,808,862**	0 -	-276,800 **0**	-276,800 **0**
Net Vol Change (calculated)	-1,808,862 [e] **-1,808,862** [e]	807,814 -	-246,234 **924,967**	561,580 **924,967**
Volume Removed (Olsen & Assoc. estimated)	1,562,811 [f]			
% of Orig Loss Replaced during Period		45% -	-14% **51%**	31% **51%**

[a] IP = Immediate Post Dredging estimate for August 1990. A survey was not taken at this time. Therefore, volume changes were estimated using Great Lakes Dredge and dock company reports (daily performance records). Post dredge bottom depths were 10 ft below grade and consistent across the bottom.

[b] Survey conducted between May and July 1994. Exact date unknown.

[c] Uncorrected survey results

[d] Corrected survey results **(in bold)**

[e] Represents calculated volume of removed sediment.

[f] Represents estimated volume of sediment removed by dredging company (Olsen Associates, Inc., C. Creed pers. comm.).

Volume of Sediment Still Missing (yds3)	**883,895**
Avg % Orig Loss Replaced/Year:	9%
Estimated Total Years to Replace:	11.6

At this rate, the borrow area should be filled by May, 2002.

of the Gaskin Banks shoal based on the 1988 survey. The entrance to the narrow channel excavated by the dredge at this location was also unclear, but it is likely to have been in the vicinity of the boundary we defined based on the draft of the dredge and natural bottom depths.

Using the revised boundary (red line) and assuming the area within the boundary was dredged uniformly to a depth of 10 ft (3.1 m) below the existing bottom grade, we calculated that 1,319,844 cu. yds. had been removed from the Joiner Bank site and 1,808,862 cu. yds. had been removed from the Gaskin Banks site. The estimate for Joiner Bank was slightly less (91%) than the volume estimated to have been removed by the dredging company (Table 2). The estimate for Gaskin Banks, on the other hand, was greater (115%) than the dredging company's estimate (Table 3). Several factors could account for these differences.

- Our boundary locations may have been inaccurate due to the lack of any immediate post-dredge surveys. While this is likely, our boundary was based on clear evidence of a depression in the bottom topography during the 1994 survey, and it even excluded possible excavated areas along the eastern and western boundaries of Gaskin Banks (Figure 22)
- The area was not dredged to a uniform depth of –10 ft (-3 m) below grade. This is also likely to have occurred, particularly along the boundary lines where sediments would have slumped into the dredged hole during or immediately after dredging.
- The estimates provided by the dredging company (daily performance records) are inaccurate. This is less likely than factors 1 and 2, but it may have contributed to part of the discrepancy.

Regardless of the reason for the differences in sediment volume estimates, the boundary lines of the borrow area we identified should be reasonable to assess refilling rates since the boundary used in each area for computing subsequent sediment deposition was kept constant. Additionally, the boundary we used as the actual borrow site is much more accurate than the boundary provided by the dredge contractor because there was clear evidence that the dredged hole at Gaskin Banks was not in the location reported.

The 1994 bathymetric survey completed by Olsen Associates, Inc. (Creed, 1995) clearly showed evidence of a large hole remaining in the Gaskin Banks shoal, but the hole at Joiner Bank had largely filled (Figures 19,22). This survey represented a recovery period of 4.5 years from the end of the dredging project. By 1994, more than 800,000 cu. yds. (55%) of sediment we estimated had been removed from the area was still missing from the Gaskin Banks site. Over this same time period, approximately 1.0 million cu. yds of sediment had been deposited in the Joiner Bank site. This represented replacement of 84% of the sediment volume that we estimated was originally removed. The more rapid filling of the Joiner Bank site is probably due to its location and depth. Joiner Bank represents an ebb-tidal shoal that is quite shallow and it receives much more wave action than the deeper Gaskin Banks shoal, which is well away from the entrance channel of either Port Royal or Calibouge Sounds. As a result, bottom sediments in the vicinity of this borrow site appear to be redistributed more quickly than at Gaskin Banks.

Evaluation of the 1996 survey results completed by the CMWS indicated relatively little change in the volume of sediments deposited between 1994 and 1996 at the Joiner Bank site (Table 3, Figures 19-20). The slightly lower estimate of deposited material in 1996 versus 1994 was probably the result of errors attributable to a lack of data in some portions of the borrow site in the 1996 survey, combined with extrapolation errors that would have occurred between the two surveys due to differences in the number of transects taken in the two areas. Bathymetric data could not be taken in the eastern portion of the borrow site during the 1996 survey due to the presence of shoals, which precluded the survey vessel from working safely in that area. This would suggest that that portion of the area had completely filled, and the only remnant of the hole was located in the western portion of the site (Figure 20). Although there was distinct evidence of a small hole still present in this area in 1996, the site had largely refilled prior to this survey, and it is possible that the bottom depression noted in the borrow site during 1996 was due to other dynamic changes in this shoal.

The much slower refilling rate in the Gaskin Banks borrow area was reconfirmed by the 1996 survey. We can not explain the differences in bathymetry readings between the 1994 and 1996 surveys both inside and outside the borrow site (approx. 2 ft difference), but it is likely that the 1996 survey database was not properly corrected for tidal stage. When the data were corrected to make it compatible with the 1988 and 1994 surveys, the estimated volume of sediment deposited in the area by 1996 had increased to 924,967 cu. yds. (Table 4). This was approximately 117,000 cu. yds. more than observed in 1994, but there was still a very obvious, deep hole present at the Gaskin Banks site. Given the rates of deposition observed, we estimate that this area would require at least 12.5 years to refill completely.

In 1997, the area surrounding the Gaskin Banks borrow site was again dredged as part of another renourishment project for Hilton Head Island. Permit requirements for this project include continued monitoring of the borrow site to better identify physical changes that occur there. However, since the new dredging activity removed much of the sand surrounding the old site, it is likely that the original borrow site will now take much longer to fill than we have estimated based on the historical filling rate.

Surficial Sediment Surveys:

The sample locations and sediment composition data obtained by the CMWS in 1996 at Joiner Bank are shown in Figure 24 and Table 5. Due to adverse conditions in the "panhandle" of the borrow site, only one grab sample (JB-BS-10) was collected within that area. This sample deviated from published pre-dredge conditions more than the other samples in that it was composed of 18% shell fragments and the total

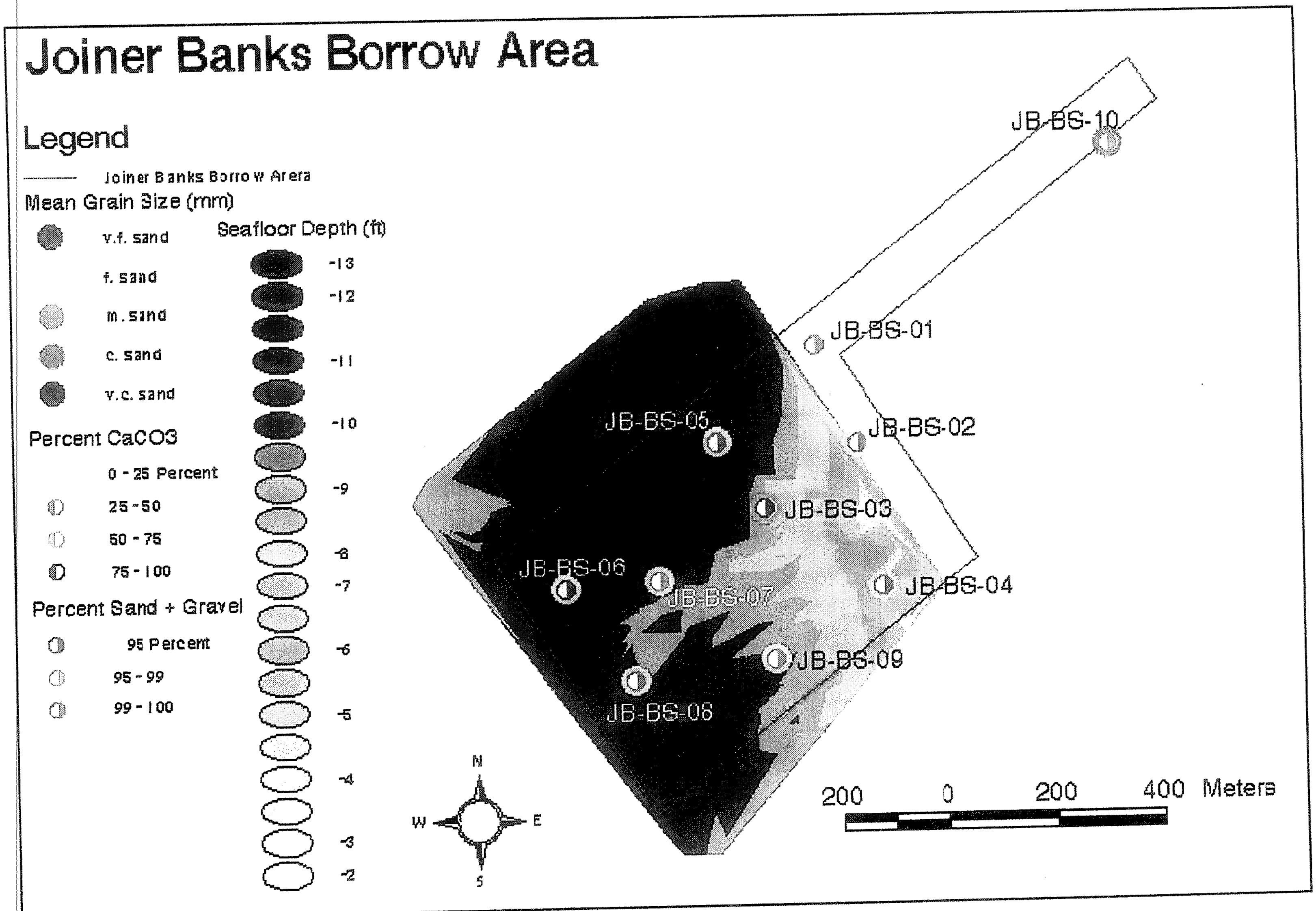

Figure 24. Location of stations sampled at the Joiner Bank borrow site by Coastal Carolina University during the 1996 survey, with summary information on sediment grain size and composition overlaid on the 1996 bathymetry data.

Table 5. Textural parameters of surficial sediments at Joiner Bank June, 1996. Skewness and kurtosis values are provided for each bulk sample (B) and for the non-carbonate fraction (NCF) after shell was removed by acid dissolution.

Sample ID	Latitude(N)	Longitude(W)	% Gravel		% Sand		% Silt/Clay		% CaCO3	Mean Grain Size		Sorting		Skewness		Kurtosis	
			B	NCF	B	NCF	B	NCF	B	B	NCF	B	NCF	B	NCF	B	NCF
JB-BS-02	32 11' 46.28"	80 39' 14.90"	0.00	0.00	99.97	99.97	0.03	0.03	1.12	0.22	0.21	0.43	0.44	-0.93	-0.55	6.66	5.13
JB-BS-04	32 11' 37.67"	80 39' 10.24"	0.00	0.08	99.82	99.76	0.18	0.16	2.60	0.22	0.21	0.42	0.45	-0.31	-0.77	9.05	10.29
JB-BS-05	32 11' 46.49"	80 39 22.01"	0.00	0.00	99.69	99.70	0.31	0.30	2.67	0.14	0.15	0.45	0.46	-0.52	-0.14	11.18	8.11
JB-BS-01	32 11' 52.29"	80 39' 14.90"	0.30	0.00	99.68	99.97	0.02	0.03	1.88	0.23	0.23	0.66	0.59	-1.86	-1.61	8.26	7.43
JB-BS-08	32 11' 32.13"	80 39' 28.16"	0.51	0.00	99.10	99.60	0.39	0.40	2.30	0.19	0.17	0.52	0.42	-2.25	0.16	23.72	12.68
JB-BS-07	32 11' 38.11"	80 39' 26.30"	0.00	0.00	98.96	98.92	1.04	1.08	2.45	0.17	0.17	0.49	0.46	1.05	1.69	10.20	11.30
JB-BS-09	32 11' 33.34"	80 39' 18.09"	0.00	0.00	97.86	97.89	2.14	2.11	3.26	0.15	0.15	0.54	0.52	1.21	1.35	8.92	9.08
JB-BS-06	32 11' 37.73"	80 39' 26.30"	0.23	0.00	94.23	94.95	5.54	5.05	8.93	0.14	0.13	0.75	0.63	0.18	1.36	8.46	7.50
JB-BS-03	32 11' 42.41"	80 39' 18.67"	12.69	10.25	82.45	84.25	4.85	5.50	8.38	0.27	0.22	1.82	1.72	-1.31	-1.58	4.16	5.24
JB-BS-10	32 12' 4.23"	80 38' 53.74"	23.24	13.81	73.51	82.03	3.25	4.16	17.95	0.66	0.47	1.90	1.75	0.00	-0.08	2.40	2.72
Composite Average			**3.70**	**2.41**	**94.53**	**95.70**	**1.78**	**1.88**	**5.15**	**0.24**	**0.21**	**0.80**	**0.74**	**-0.47**	**-0.02**	**9.30**	**7.95**

sample had a mean grain size of 0.66mm. It also contained 23% gravel size grains (approximately 50% of the coarse fraction was shell fragments), 74% sand and 4% silt & clay. Prior to dredging, the borrow site was predominantly characterized by sandy sediments (approx. 95%) with a mean grain size of 0.19 and very little shell hash or mud (Van Dolah et al., 1992, Creed, 1995). The grain size of this site is substantially greater than the mean grain size of the native beach at Hilton Head Island.

Of the nine samples within the main body of the Joiner Bank borrow area, the mean grain size (0.19 mm) is identical to the pre-dredge mean for the borrow site. Some individual samples were found to be finer than observed in pre-dredge samples and were also positively skewed (JB-BS-06, JB-BS-07 and JB-BS-09). This suggests that those sites are an area of active deposition. Since the site had largely filled prior to 1996 the surficial sediment characteristics may well reflect the natural variability in this dynamic shoal area.

Figure 25 shows a compilation of the change in percent fines through time from various studies from 1990 through 1996. This figure represents the composite average percent sand and percent silt/clay (fines) from the various collections since 1990 in the Joiner Banks borrow area. It should be noted that the 1990 collections had a smaller number of samples within the borrow area but the composite average appears illustrative of the surficial sediment characteristics through time.

Van Dolah et al. (1992) reported sediments accumulating in the Joiner Bank borrow site were markedly finer (unconsolidated muddy sediments) than the pre-dredging fine sands during the 12 month period following dredging. Olsen and Associates (sampling in 1994) showed the surficial sediment had begun to revert back to pre-dredge conditions but noted an area of fine grained sediments (mean grain size less than 0.1 mm and greater than 10 % silt and clay by weight) persisted along the northwestern edge of the borrow area (Creed, 1995). The coarsest mean sediment size of the 1990 samples at the Joiner Bank borrow site was 0.25 mm. This sample was located in the northern corner of the borrow area near a narrow panhandle shaped portion of the borrow area that extended to the northeast. That is an area that continued to be generally coarser grained than the rest of the borrow site in 1996.

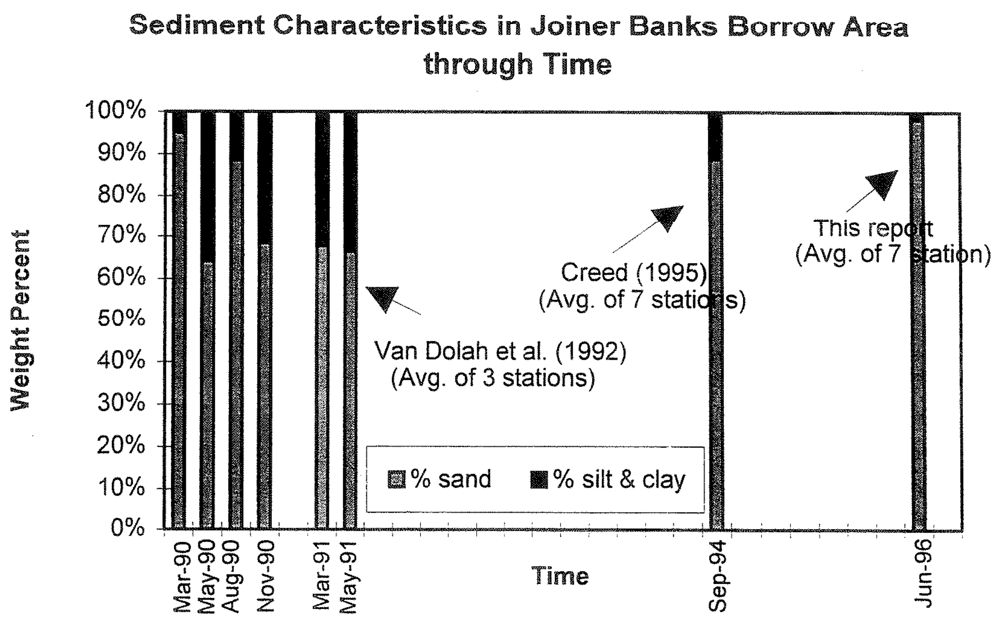

Figure 25. Summary of sediment characteristics through time at the Joiner Bank Borrow site

By June 1996 the Joiner Bank borrow area was composed of greater than 95 percent sand and gravel size sediment and generally less than 5 % coarse shell hash. No "muddy" areas were identified by the sediment samples collected in 1996. The site is influenced by shoaling waves, strong tidal currents and is therefore very dynamic. There is sedimentologic evidence for active sediment (positively skewed distributions) infilling at three sites within the borrow area (JB-BS-06, JB-BS-07 and JB-BS-09). The differences observed between surveys could be related to natural sand movements expected within the shoal system rather than any lingering impact of the 1990 dredging on the surficial sediment characteristics at the site.

In general, it appears that the Joiner Bank borrow area experienced a rapid infilling that was initially much finer grained than the native sands at the site. By 1994, most of the site was covered by sand that was slightly finer than the native sediment. By 1996, fine sediments were not identified and the surficial sand characteristics had reverted to the pre-dredging condition. It is probable that the clean, beach-compatible sands found in 1996 cap a layer of much finer-grained sediments that initially were present in the borrow site. Although some reworking of the fill has probably occurred, there may still be a clear gradient in sediment grain size with depth below grade in this borrow site.

The sample location and sediment composition data (by the CMWS in 1996) at Gaskin Banks are shown in Figure 25 and Table 6. All of these samples had >95% sand and gravel (mean for 11 samples 99.2%) and low (<4%) silt and clay fractions. The mean grain size of the samples ranged from 0.13-0.21 mm and the average of the 11 samples (0.18 mm) was slightly coarser than the pre-dredge mean (0.15 mm).

The Gaskin Borrow area is distinctly lacking in coarse gravel size fractions and typically lower in percent carbonate than the Joiner Bank borrow site. Only two samples (GB-BS-04 and GB-BS-06; average mean grain size 0.14) showed a mean grain size less than the pre-dredge mean for the borrow area. These two samples were from the deepest and axial portion of the bathymetric depression remaining in 1996. Two sites (GG-BS-2 and GB-BS-7) showed textural characteristics (positive skewness) that may indicate active infilling. Three other sites (GB-BS-1, GB-BS -4, and GB-BS-11) are also indicative of active sedimentation, but not strongly so.

Van Dolah *et al.* (1992) reported that changes in the surficial sediment characteristics of the Gaskin Banks borrow site were minimal during the12 month period following the dredging. In June 1996, the surficial sediment was characterized almost entirely by clean, well-sorted, fine sand, and the sediment characteristics were less variable than the Joiner Bank borrow area. The composite average mean grain size of samples in the area that was actively dredged was 0.18 mm, which is identical to the pre-

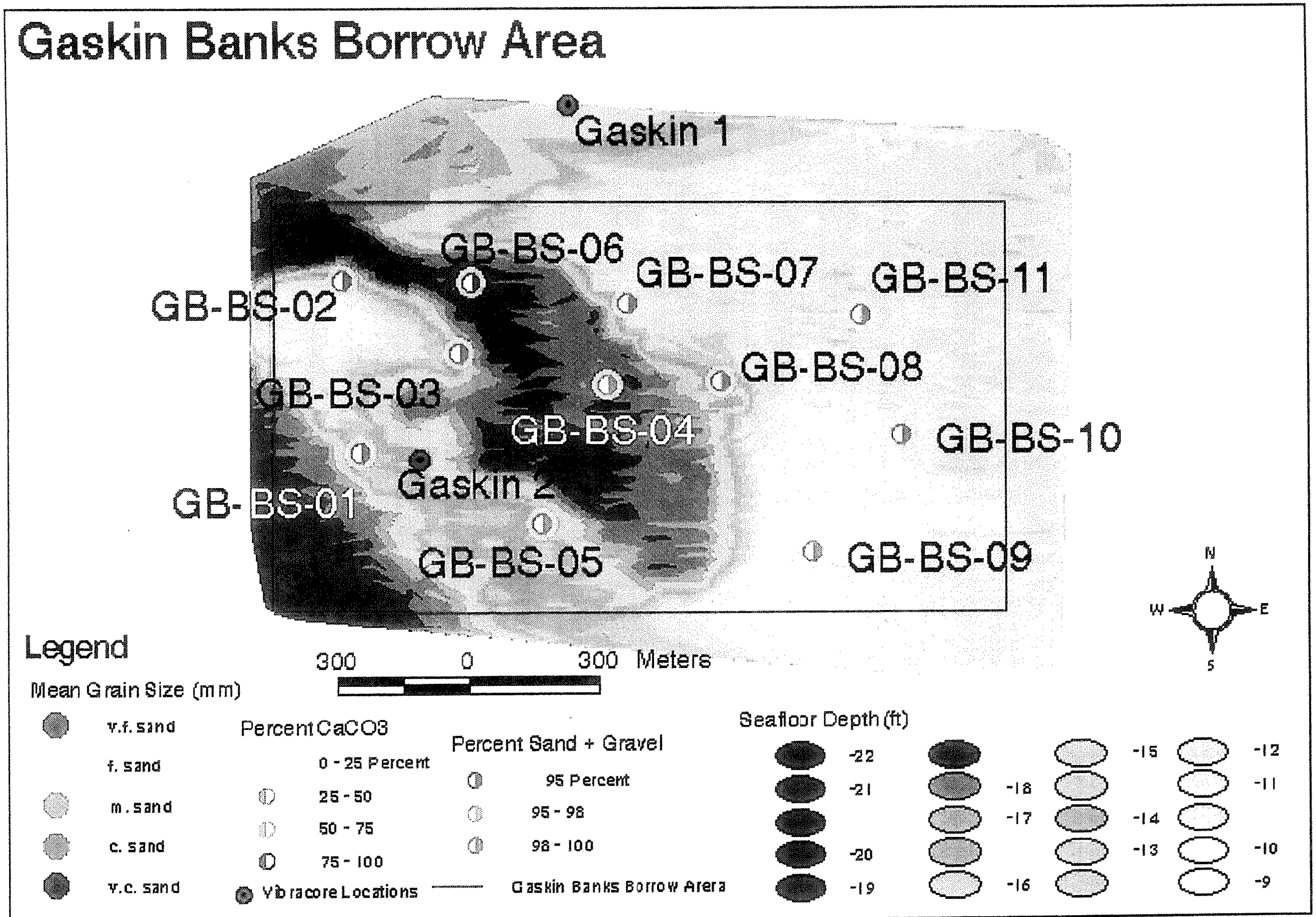

Figure 26. Locations of stations sampled at the Gaskin Banks borrow site by Coastal Carolina University during the 1996 survey, with summary informatior on sediment grain size and composition overlaid on the 1996 bathymetry data.

Table 6. Textural parameters of surficial sediments at Gaskin Banks in June, 1996. Skewness and kurtosis values are provided for each bulk sample (B) and for the non-carbonate fraction (NCF) after shell was removed by acid dissolution.

Sample ID	Latitude (N)	Longitude (W)	% Gravel		% Sand		% Silt/Clay		% CaCO3	Mean Grain Size		Sorting		Skewness		Kurtosis	
			B	NCF	B	NCF	B	NCF	B	B	NCF	B	NCF	B	NCF	B	NCF
GB-BS-10	32 6' 31.18"	80 43' 23.54"	0.00	0.17	99.98	99.74	0.02	0.09	2.15	0.17	0.17	0.38	0.44	-0.58	-2.46	8.28	29.30
GB-BS-03	32 6' 37.22"	80 44' 2.59"	0.00	0.00	99.95	99.93	0.05	0.07	1.15	0.20	0.19	0.41	0.32	-0.71	-0.25	6.72	13.70
GB-BS-05	32 6' 24.72"	80 43' 55.35"	0.00	0.00	99.84	99.82	0.16	0.18	1.60	0.21	0.22	0.43	0.37	-0.61	0.09	8.88	10.80
GB-BS-02	32 6' 42.44"	80 44' 12.67"	0.00	0.00	99.82	99.82	0.18	0.18	2.20	0.19	0.19	0.29	0.28	2.11	1.91	17.09	19.34
GB-BS-08	32 6' 35.06"	80 43' 39.52"	0.09	0.00	99.78	99.85	0.13	0.15	2.25	0.18	0.19	0.48	0.38	-1.47	0.14	12.06	10.09
GB-BS-01	32 6' 29.84"	80 44' 11.15"	0.00	0.00	99.72	99.71	0.28	0.29	2.26	0.21	0.22	0.39	0.39	0.70	0.82	10.42	10.72
GB-BS-11	32 6' 39.99"	80 43' 27.24"	0.00	0.00	99.61	99.52	0.39	0.48	2.63	0.16	0.18	0.36	0.37	0.71	1.67	12.03	13.17
GB-BS-07	32 6' 40.76"	80 43' 47.74	0.00	0.00	99.54	99.50	0.46	0.50	2.35	0.18	0.19	0.35	0.34	1.81	2.29	16.11	18.13
GB-BS-09	32 6' 22.60"	80 43' 31.44"	0.00	0.15	99.44	99.28	0.56	0.57	2.36	0.17	0.18	0.46	0.48	-0.29	-0.93	12.47	18.77
GB-BS-04	32 6' 34.89"	80 43' 49.64"	0.00	0.08	98.18	98.12	1.82	1.81	5.87	0.13	0.14	0.51	0.54	0.22	-0.18	13.83	16.48
GB-BS-06	32 6' 42.27"	80 44' 1.46"	0.00	0.00	95.49	95.25	4.07	4.75	11.01	0.14	0.13	0.87	0.73	-1.12	-0.50	7.92	8.48
Composite Average			**0.01**	**0.04**	**99.21**	**99.14**	**0.74**	**0.82**	**3.26**	**0.18**	**0.18**	**0.45**	**0.42**	**0.07**	**0.24**	**11.44**	**15.36**

dredge values reports for the native beach at Hilton Head and slightly coarser than the reported native sands at the borrow site.

Sediments accumulating in the main bathymetric depression of the borrow site are slightly finer than the native mean grain size and they contain a higher percentage of silt and clay (3% average) than samples collected prior to dredging (Van Dolah *et al.*, 1992). However, these differences do not represent a substantial deviation from the native surficial sands at the Gaskin Banks borrow area and the data should be interpreted carefully in light of the small number of samples collected.

Only one of the two vibracore samples collected in November, 1996 at the Gaskin Banks borrow area was located in the area dredged in 1991 (Figure 25). Both contained largely homogeneous very fine sands, with no apparent lenses of mud (Appendix 1). The longest core showed some localized concentration of heavy minerals which would reflect minor winnowing from high energy events. As with the surficial grab samples, the upper 0.5 meter layer of sand was very similar to the pre-dredging surficial sediments in the borrow area.

Hunting Island Borrow Site:

Bathymetric Surveys:

The borrow site used for the 1991 renourishment of Hunting Island was located in an area that was about 12 ft below MSL (CSE-Baird, 1996b and Figure 26). This depth was similar to the original depth of the Gaskin Banks site dredged off Hilton Head Island. No comprehensive pre-dredge survey data were available for the Hunting Island site, but two survey transects were taken by CSE-Baird along the length and width of the borrow site in 1996, both before and after dredging. This information, combined with our interpolation of the borrow site limits provided by CSE-Baird, were used to develop the "assumed" borrow site boundary (dashed line, Figure 26). Based on the 1996 survey completed by the CMWS, the boundary was further modified in the southeastern portion of the area to include an obvious depression outside the original boundary site limits (red line, Figure 26). Using the corrected boundary site limits and the information provided by CSE-Baird on dredging depths within the site, we estimated 821,339 cu. yds. of material had been removed from the borrow site in 1991 (Table 7). This estimate was only slightly greater than CSE-Baird's estimate of 757,644 cu. yds. removed.

By the 1996 survey (5.2 years post-dredging), more than 562,000 cu. yds. had been deposited in the borrow site, but there was still a very distinct hole in the borrow area compared to the surrounding bottom (Table 7, Figure 26). Bathymetric contours within the borrow area suggest that more of the sediment fill was present in the western portion of the site, compared to the eastern side, where bottom depths were greatest. This would suggest that sediments were slumping into the area from shallower depths on the landward side of the borrow site.

The volume of sediments deposited in the borrow site by 1996 represented replacement of approximately 68% of the material that we estimated was originally removed (Table 7). Based on this refilling rate, the site would probably be completely refilled after 7.7 years. This refilling rate is similar to our estimate for Joiner Bank and shorter than our estimate for Gaskin Banks.

Surficial Sediment Survey

The surficial sediment characteristics of the Hunting Island borrow area were significantly different in the area actively dredged in 1991 compared to the surrounding non-impacted area (Figure 27, Table 8). Within the dredged area, the surficial sediments consisted of a 95-97% sand and gravel fraction and the mean grain size for the bulk samples ranged from 0.12 - 0.13 mm (average of five samples = 0.12mm and 4.5 % silt clay). Outside the dredged area, but still within the defined borrow area, the samples ranged from 98-100% sand and gravel and mean grain sizes ranged from 0.15-0.98 mm (average of eight samples = 0.46mm and mean of 0.6 percent silt clay).

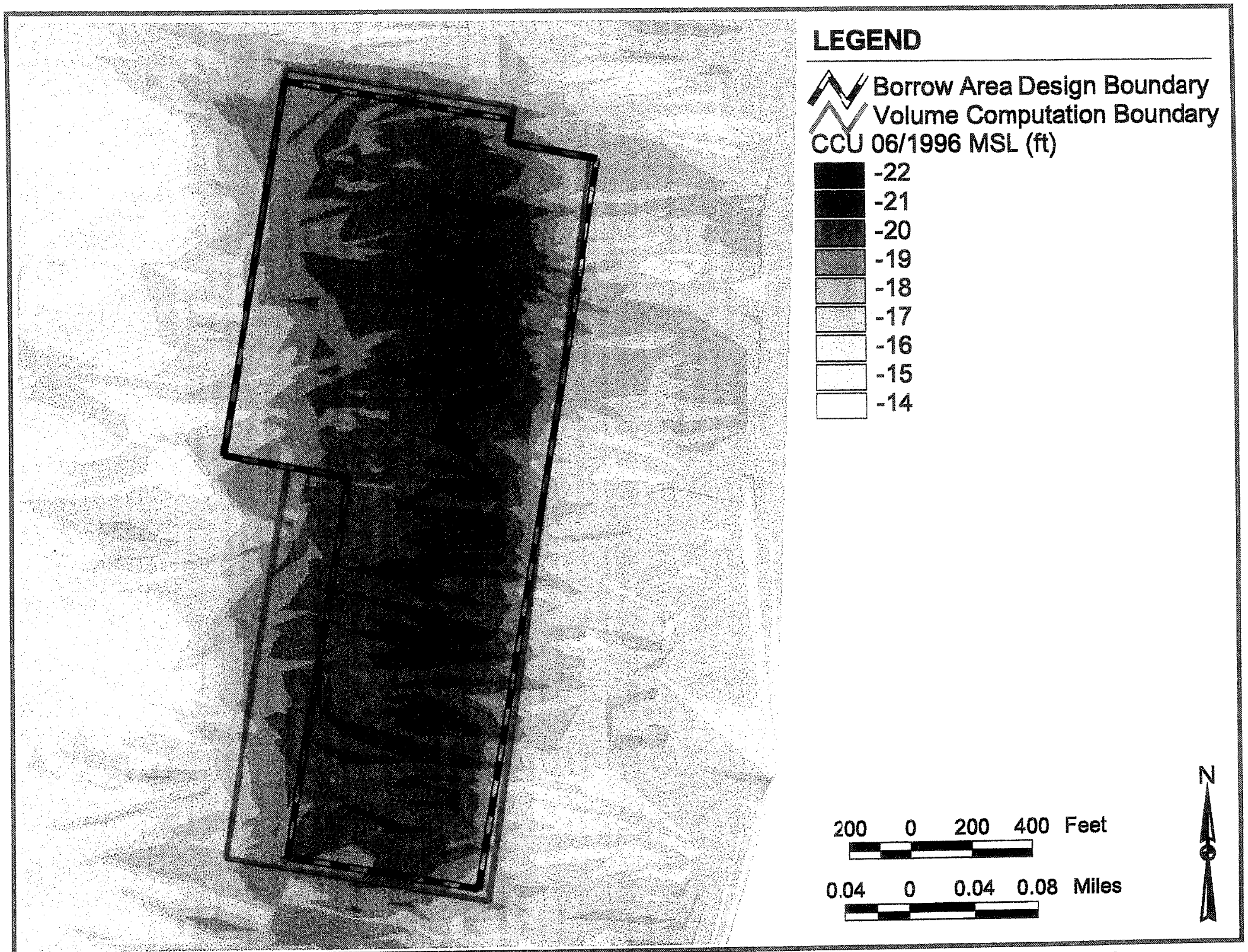

Figure 27. Hunting Island borrow site with bathymetric data from the 1996 post-construction survey conducted by Coastal Carolina University.

Table 7. Volume change analyses measuring sediment deposition within the Hunting Island borrow site following dredging activities in February and March, 1991. The 1996 survey was conducted by Coastal Carolina University.

	Time Periods Between Bathymetric Surveys		
	Pre-IP*	IP-June 96	Totals
Time Period between Surveys (Years)		5.17	5.17
Deposited Volume (cubic yards)	0	561,575	561,575
Removed Volume (cubic yards)	-821,339	0	0
Net Vol Change (Calculated)	-821,339**	561,575	561,575
Volume Removed (CSE-Baird estimated)	-757,644***		
% of Orig Loss Replaced during Period		68%	68%

* IP = Immediate Post dredging estimate for March 1991. A survey was not taken at this time. Therefore, volume changes were estimated using reports which stated the volume of sediment dredged and the depth to which dredging occurred. The depth of dredging (-26 feet NGVD) was consistent across the bottom.

** Represents calculated volume of removed sediment.

*** Represents estimated volume of removed sediment. Data provided by Baird Associates, T. Kana, pers. comm.).

Volume of Sediment Still Missing	259,764
Avg % Orig Loss Replaced/Year:	13%
Estimated Total Years to Replace:	7.7

At this rate, the borrow area should be filled by November 1998.

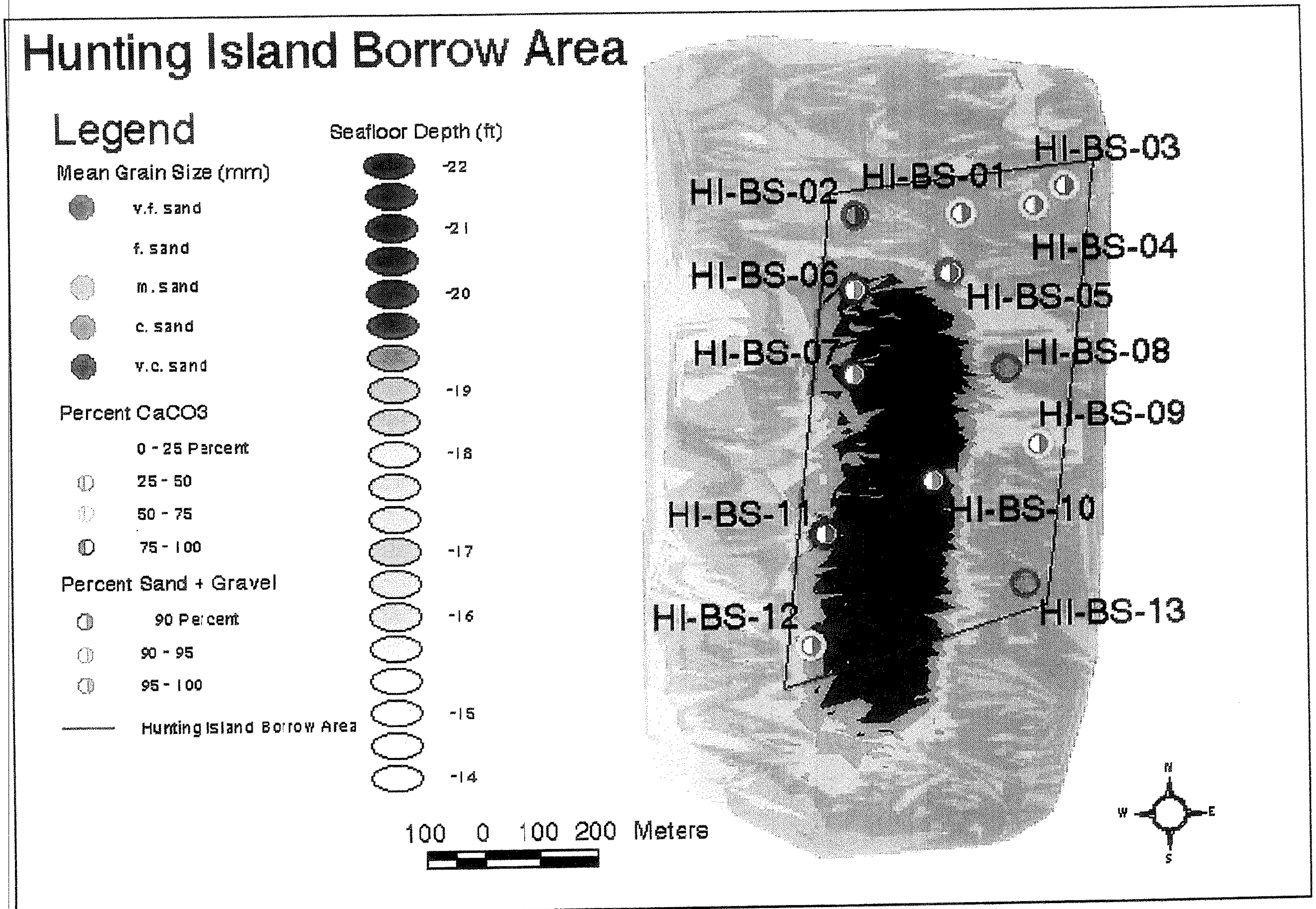

Figure 28. Location of stations sampled at the Hunting Island borrow site by Coastal Carolina University during the 1996 survey, with summary information on sediment grain size and composition overlaid on the 1996 bathymetry data.

Table 8. Textural parameters of surficial sediments at the Hunting Island borrow site in June, 1996. Skewness and kurtosis values are provided for each bulk sample (B) and for the non-carbonate fraction (NCF) after shell was removed by acid dissolution.

Sample ID	Latitude(N)	Longitude (W)	% Gravel		% Sand		% Silt/Clay		% CaCO3	Mean Grain Size		Sorting		Skewness		Kurtosis	
			B	NCF	B	NCF	B	NCF	B	B	NCF	B	NCF	B	NCF	B	NCF
HI-BS-09	32 21' 49.79"	80 24' 13.77"	0.39	0.00	98.56	98.92	1.05	1.08	4.71	0.15	0.15	0.66	0.53	-2.10	0.03	17.08	8.94
HI-BS-03	32 22' 4.60"	80 24' 11.69"	1.13	0.00	97.63	98.64	1.24	1.36	6.88	0.15	0.14	0.78	0.52	-2.91	-0.53	18.57	13.14
HI-BS-04	32 22' 3.47"	80 24' 13.77"	1.97	0.00	97.30	99.37	0.73	0.63	6.18	0.16	0.14	0.91	0.49	-3.48	-0.39	19.27	7.65
HI-BS-05	32 21' 59.71"	80 24' 19.54"	3.03	0.62	96.76	99.14	0.21	0.24	19.36	0.71	0.64	0.78	0.71	0.49	1.37	7.67	8.56
HI-BS-12	32 21' 38.41"	80 24' 29.37"	0.00	0.00	96.59	97.22	3.41	2.78	7.18	0.13	0.13	0.60	0.55	0.27	0.82	8.98	8.82
HI-BS-01	32 22' 3.07"	80 24' 18.65"	2.74	0.00	96.22	98.84	1.05	1.16	8.34	0.17	0.15	1.02	0.53	-2.76	0.23	13.13	7.95
HI-BS-11	32 21' 44.79"	80 24' 28.28"	0.31	0.00	96.09	96.30	3.60	3.70	7.70	0.12	0.11	0.61	0.52	-1.45	1.06	25.05	10.29
HI-BS-06	32 21' 58.83"	80 24' 26.08"	0.41	0.00	94.66	95.10	4.93	4.90	9.25	0.12	0.12	0.71	0.59	-0.68	1.02	12.71	9.24
HI-BS-07	32 21' 54.00"	80 24' 26.17"	0.29	0.10	94.16	93.96	5.55	5.94	9.15	0.11	0.12	0.74	0.66	-1.31	0.23	13.47	10.89
HI-BS-10	32 21' 47.58"	80 23' 45.96"	0.49	0.00	93.97	93.81	5.54	6.19	9.62	0.12	0.11	0.76	0.64	-0.99	0.52	12.09	8.14
HI-BS-08	32 21' 54.22"	80 24' 15.75"	5.82	0.81	93.92	98.78	0.26	0.41	30.26	0.71	0.56	1.05	0.97	0.63	0.94	4.15	4.54
HI-BS-13	32 21' 41.75"	80 24' 14.78"	5.94	0.96	93.87	98.74	0.20	0.30	27.56	0.64	0.49	1.20	1.11	0.35	0.49	3.18	2.93
HI-BS-02	32 22' 2.99"	80 24' 25.85"	10.40	2.54	89.60	97.43	0.00	0.04	36.19	0.98	0.76	0.94	0.88	0.06	0.84	4.08	4.48
Composite Average			**2.63**	**0.39**	**96.33**	**97.40**	**2.14**	**2.21**	**14.03**	**0.33**	**0.28**	**0.83**	**0.67**	**-1.07**	**0.61**	**12.26**	**8.12**

The 1991 renourishment was the fifth project at Hunting Island since 1968 and sediment loss along Hunting Island's beach has been estimated to be 250,000 cy/yr prior to the renourishment (USACOE, 1964, 1977). The native beach sands at Hunting Island were reported to be 0.18 mm prior to renourishment (USACOE, 1977) and 0.22 mm subsequent to the initial nourishment project. An assessment of the Hunting Island site in 1990 reported the mean grain size of the native beach to be 0.15 mm (mean of 5 samples from the berm) and 0.18 mm (mean of 5 samples from along the mid beach) (CSE, 1991). The bottom sediment in the borrow site in 1990 was characterized by composite samples of the upper three feet vibracores. The range of grain size in all cores from the shoal area in 1990 was from 0.11 to 0.24 mm (CSE, 1991); the mean of four core tops (upper meter) from the borrow area was 0.22 (CSE, 1991).

Some of the sediment surrounding the dredged area is substantially coarser than the native beach sands and may be unacceptable for placement on the beach. It is presumed, however, that a coarser fill may be more stable (CSE, 1991). An area of coarser sediment was found outside of the northern border of the borrow area dredged in 1991. This zone had a mean grain size of nearly 1 mm. Within the depression remaining since the dredging operation, the mean grain size of the surficial sediment in 1996 ranged from 0.114 mm to 0.126 mm (average mean of HI-BS-06, 07, 10, 11 and 12 is 0.12 mm). This was significantly finer than the native sand from the site (mean 0.22 mm) and was also finer than the native beach sands at Hunting Island (0.15 mm along the BERM and and 0.18 along the mid-beach).

While only two samples exceeded 5 % silt and clay by weight and might be considered too fine for use in renourishment, the 1991 dredging operation resulted in sediments with a grain size similar to that observed at Joiner Banks. At Joiner Bank, the initial fill was very silty, but had become similar to the pre-dredging condition by the fifth year following dredging and largely indistinguishable from the pre-dredge conditions by the sixth year following dredging. Core samples collected in this borrow area by Coastal Science and Engineering (CSE-Baird, 1996a) in June of 1996 indicated that a similar trend in deposition had occurred at the Hunting Island site due to the presence of muddy sediments below a cap of clean sand. The mud content in the lower sediments ranged from 5-33% silt/clay. CSE-Baird (1996a) also noted that considerable "free" mud can occur in this area, with the mud lens occasionally exceeding one foot in thickness.

Edisto Island Borrow Site:

Bathymetric Surveys:

The volume of sediment removed from the Edisto Island borrow site was the smallest of those we could analyze. Based on the pre- and post-dredge survey data available from CSE-Baird (1996b), combined with their information on the coordinates and dredged depths of the borrow site, we computed that 157,835 cu. yds. were removed by the dredging operation (Figure 29, Table 9). This estimate was very close to the 150,000 cu. yds. estimated to have been removed by CSE-Baird (1996b). By June of 1996, about 1.2 years after dredging was completed, approximately 67% of the sediment volume lost had been replaced by new deposition based on the CMWS survey data. This represented the most rapid accumulation of material among all of the areas analyzed. The rapid recovery may be due in part to the small size of the hole, combined with the location. This shoal was located at the southern end of the island just north of the South Edisto River Inlet. Large shoals are typically found at the southern end of many South Carolina islands, and are formed by the southerly migration of sands along the beach front. This depositional process may have accelerated the filling rate for this site. The results of our analysis were consistent with findings of a more limited survey conducted in May, 1996 by CSE-Baird. They noted that only a few acres of the site remained close to the original dredging depth (CSE-Baird, 1996b).

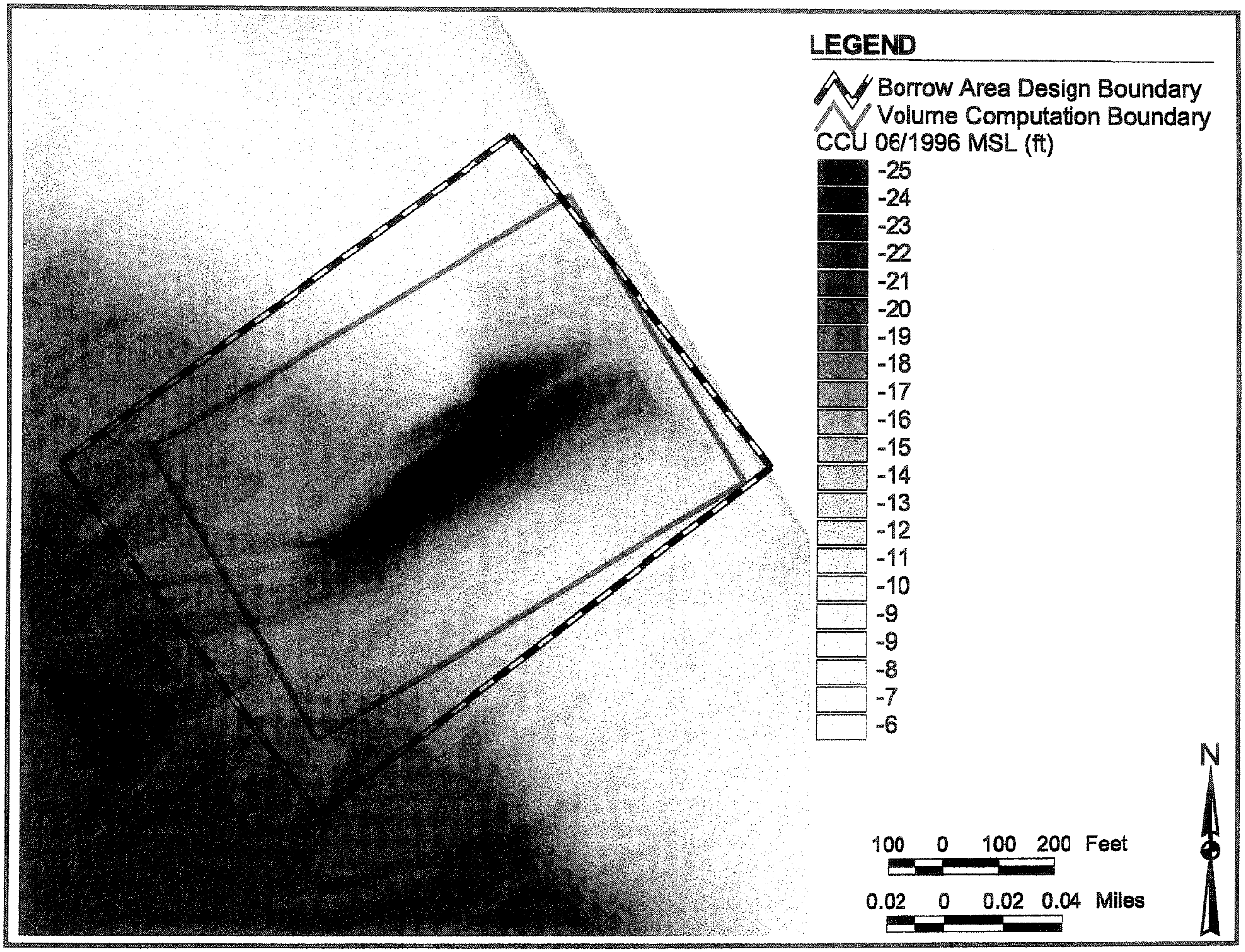

Figure 29. Edisto Island borrow site with bathymetric data from the 1996 post-construction survey conducted by Coastal Carolina University.

Table 9. Volume change analyses measuring sediment deposition within the Edisto borrow site following dredging activities in April 24-30, 1995. The 1996 survey was conducted by Coastal Carolina University. Shaded area represents natural changes in the borrow area after dredging was completed.

	Time Periods Between Bathymetric Surveys		
	Pre-IP*	IP-June 96	Totals
Time Period between Surveys (Years)		1.17	1.17
Volume Deposited (cubic yards)	0	107,516	107,516
Volume Lost (cubic yards)	-157,835	-2,197	-2,197
Net Vol Change (calculated)	-157,835**	105,319	105,319
Volume Removed (CSE-Baird estimated)	150,000***		
% of Orig Loss Replaced during Period		67%	67%

* IP = Immediate Post dredging estimate for April 1995. A survey was not taken at this time. Therefore, volume changes were estimated using reports which stated the volume of sediment dredged and the depth to which dredging occurred. The depth of dredging (-21 feet NGVD) was consistent across the bottom.

** Represents calculated volume of removed sediment.

*** Represents estimated volume of sediment placed on the beach (CSE-Baird 1996).

Volume of Sediment Still Missing (yds3)	52,516
Avg % Orig Loss Replaced/Year:	57%
Estimated Total Years to Replace:	1.75

At this rate, the borrow area should be filled by January 1997.

Surficial Sediment Survey:

The Edisto Island native beach and borrow site sands were characterized in 1991 by surficial sediment samples and several vibracores (CSE, 1992). Native beach sands were defined by the average of 24 surficial sediment samples from the base of the dunes (6 samples), berm crest (6 samples), mid-beach face (6 samples), and low tide swash (6 samples). The composite average mean grain size was 0.41 mm. A total of 27 cores were taken in the southern area proposed as a borrow area in the 1991 CSE-Baird study. Six of those vibracores were from the area dredged in 1996. Mean grain size was determined for 1-m sections of each core. The mean grain size of the borrow area determined from the composite average from these cores was 0.52 mm (CSE, 1992).

The average mean grain size from the four samples we collected within the bathymetric depression seen in 1996 was 0.64 mm (Figure, 30,Table 10). Two samples (EDBS-04 and 06) were essentially coarse shell hash (percent carbonate 64% and 26% respectively). No sample possessed more than 1 % silt/clay content. In general, the average mean grain size from samples in the dredged area was greater than that of the native sands reported from the site. The two finest grained samples came from the area impacted by the 1994 dredging (EDBS-03 and EDBS-05, Table 10). These samples were also finer than the composite native beach sand.

The seven surficial sediment samples collected within the defined borrow site but outside the area actually dredged consisted of coarse to very coarse shelly sands (average mean was 38% carbonate). The mean grain sizes of these samples ranged from 0.40 mm to 1.31 mm. All but one sample (EDBS-02) was coarser than the native borrow area sand and the native beach sand.

Three vibracores were collected by CMWS in 1996 within the defined borrow area, but not in the area actively dredged. Two more cores were collected on that same cruise to the northeast on the borrow site shoal area. Core logs are provided in Appendix

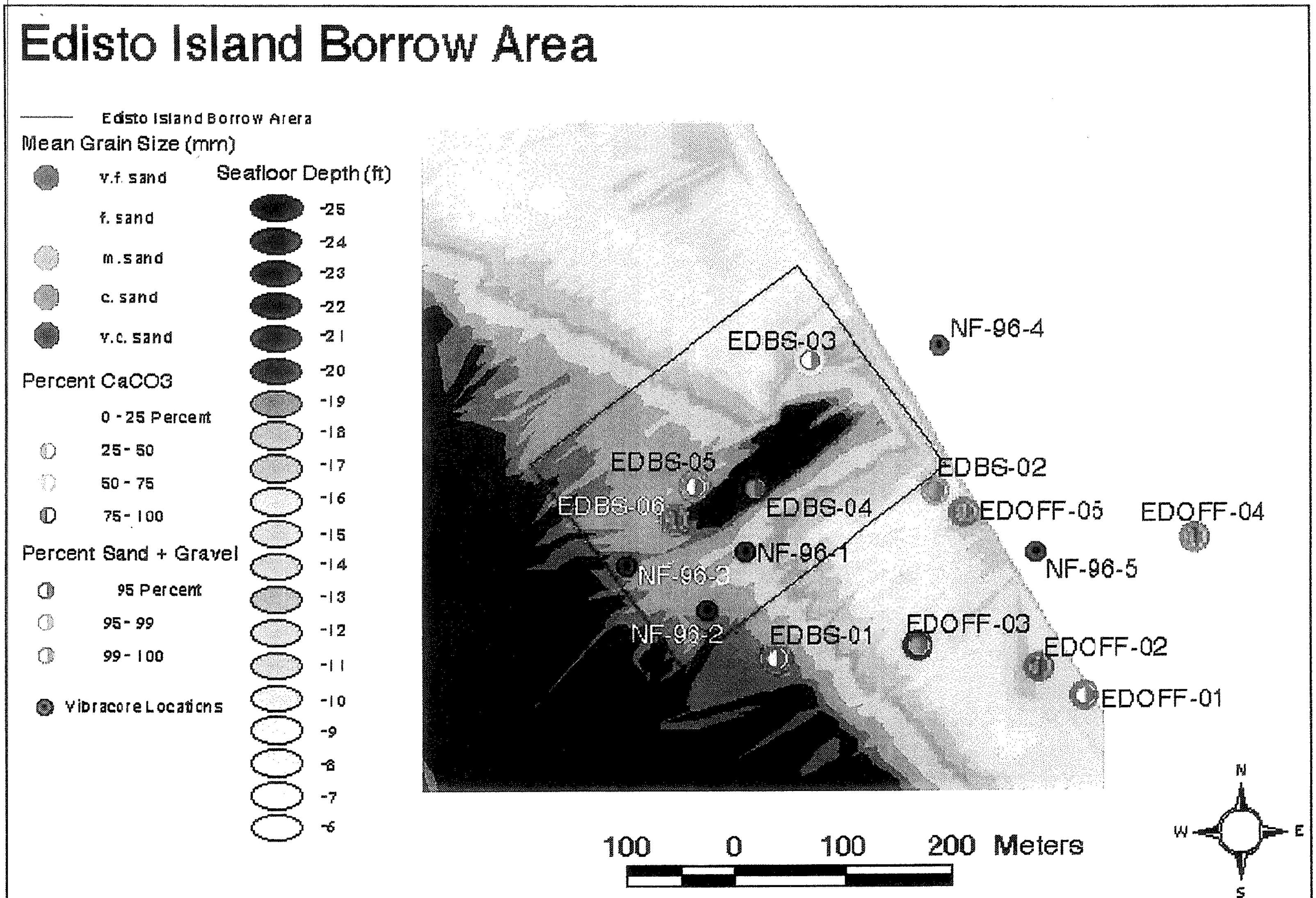

Figure 30. Location of stations sampled at the Edisto Island borrow site by Coastal Carolina University during the 1996 survey, with summary information on sediment grain size and composition overlaid on the 1996 bathymetry data.

Table 10. Textural parameters of surficial sediments at the Edisto Island borrow site in June, 1996. Skewness and kurtosis values are provided for each bulk sample (B) and for the non-carbonate fraction (NCF) after shell was removed by acid dissolution.

Sample ID	Latitude(N)	Longitude (W)	% Gravel		% Sand		% Silt/Clay		% CaCO3	Mean Grain Size		Sorting		Skewness		Kurtosis	
			B	NCF	B	NCF	B	NCF	B	B	NCF	B	NCF	B	NCF	B	NCF
EDBS-01	32 28' 2.92"	80 19' 35.33"	31.09	0.31	68.56	99.17	0.36	0.53	21.21	0.89	0.37	1.80	1.03	0.15	-0.07	1.83	2.69
EDOFF-01	32 28' 1.71"	80 19' 24.42"	0.67	0.00	98.98	99.55	0.35	0.45	17.88	0.52	0.47	0.69	0.64	0.45	1.16	7.51	9.52
EDBS-02	32 28' 7.83"	80 19' 29.61"	11.00	0.47	88.76	98.88	0.24	0.65	53.66	0.41	0.30	1.58	1.10	-0.98	-0.47	3.28	2.64
EDBS-03	32 28' 11.74"	80 19' 34.04"	1.27	0.00	98.46	99.65	0.28	0.35	12.87	0.25	0.22	0.88	0.61	-1.71	-0.69	8.01	6.57
EDBS-04	32 28' 7.94"	80 19' 36.04"	40.18	2.23	59.55	97.00	0.27	0.77	64.34	1.25	0.35	1.74	1.24	0.44	-0.36	2.15	2.50
EDBS-05	32 28' 8.0"	80 19' 38.14"	1.01	0.00	98.76	99.70	0.23	0.30	5.95	0.37	0.35	0.80	0.69	-0.39	0.74	6.61	4.39
EDBS-06	32 28' 7.04"	80 19' 38.85"	9.74	0.77	90.26	99.23	0.00	0.00	25.63	0.71	0.54	1.06	0.63	-0.87	-0.04	3.84	4.15
EDOFF-02	32 28' 2.59"	80 19' 26.06"	8.66	0.25	91.34	99.72	0.00	0.04	34.83	0.75	0.55	0.98	0.63	-0.76	0.46	4.04	4.36
EDOFF-03	32 28' 3.26"	80 19' 30.28"	27.29	1.25	72.68	98.55	0.04	0.20	64.61	1.30	0.60	1.19	0.78	-0.27	0.60	2.58	5.80
EDOFF-04	32 28' 6.42"	80 19' 20.53"	8.90	0.45	91.10	99.55	0.00	0.00	33.92	0.80	0.32	1.00	0.71	-0.89	0.32	4.44	3.92
EDOFF-05	32 28' 7.23"	80 19' 28.62"	4.18	0.35	95.82	99.65	0.00	0.00	39.58	0.82	0.85	0.71	0.61	-0.28	0.85	4.92	5.82
Composite Average			**13.09**	**0.55**	**86.75**	**99.15**	**0.16**	**0.30**	**34.04**	**0.73**	**0.45**	**1.13**	**0.80**	**-0.46**	**0.23**	**4.47**	**4.76**

1. The cores on the southwestern flank of the shoal but within the defined borrow site all contained 77 to 90 cm of medium to coarse shelly sands (0.20 - 1.35mm mean grain size). These sands capped a layer of muddy sands and inter-bedded silts and sand. The two vibracores collected on the northeastern flank of the shoal and outside the borrow site contained 60 to 66 cm of coarse sandy shell hash. No silty horizons were penetrated by these cores.

In general, the sediments accumulating within the enduring depression of the borrow site were finer grained than the borrow site and native beach sands for the site. Vibracores from the eastern edge of the borrow site showed a coarse shelly sand capping interbedded silts and sands. A similar fine grained unit was found in the pre-dredging vibracores in the area and this is not inferred to represent an early fine-grained infilling of the borrow site but a pre-existing deposit.

Seabrook Island Borrow Site:

Bathymetric Surveys:

As noted previously, the Seabrook borrow site presented the greatest problem in analyzing the recovery rate due to the lack of any immediate post-dredging data, combined with our uncertainty about exactly what portion of the planned borrow site was actually dredged. Additionally, the area dredged was immediately adjacent to a shore-parallel channel (CSE, 1989), making it even more difficult to resolve whether the depression observed in the 1996 survey completed by the CMWS was natural or a partial remnant of the borrow site depression (Figure 31). Although more information is needed to accurately define the depositional rate in this area, the 1996 survey clearly showed that most of the shoal within the surveyed portion of the borrow area had been replaced. Rapid accumulation of sediments would be expected in this area since it is located in a depositional shoal at the southern end of the Kiawah-Seabrook Island complex.

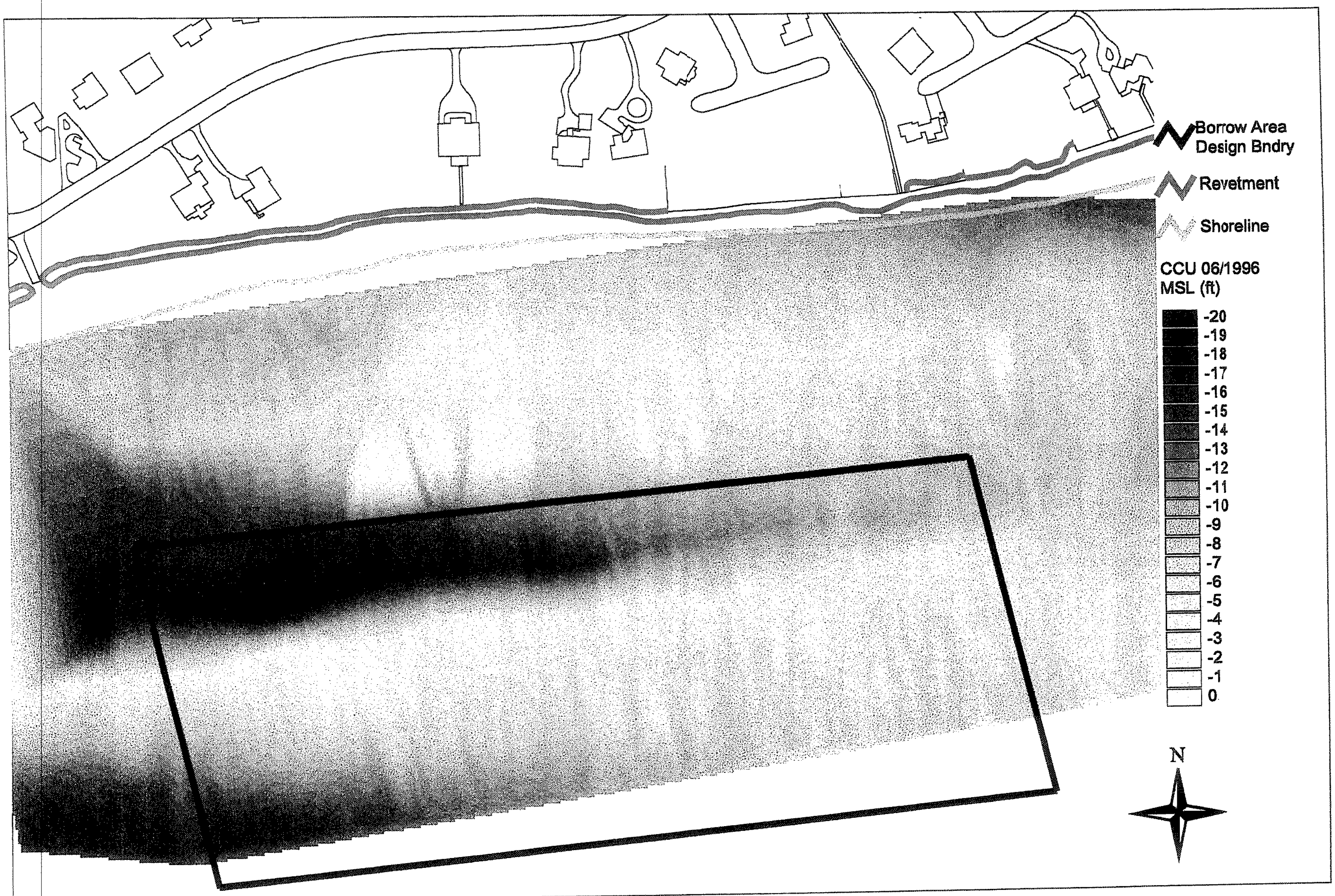

Figure 31. Seabrook Island borrow site with bathymetric data from the 1996 post-construction survey conducted by Coastal Carolina University.

Surficial Sediment Survey:

Very shallow water prevented the collection of more than 8 samples at the Seabrook borrow site (Figure 32). All of these samples contained greater than 95 % sand (average 98.9%) and mean grain sizes ranged from 0.17-0.23mm (Table 11). Native sand on Seabrook's beaches averages 0.2 mm mean grain size (Tim Kana, personal communication) so the borrow site contains material that is beach compatible for future Seabrook renourishment projects.

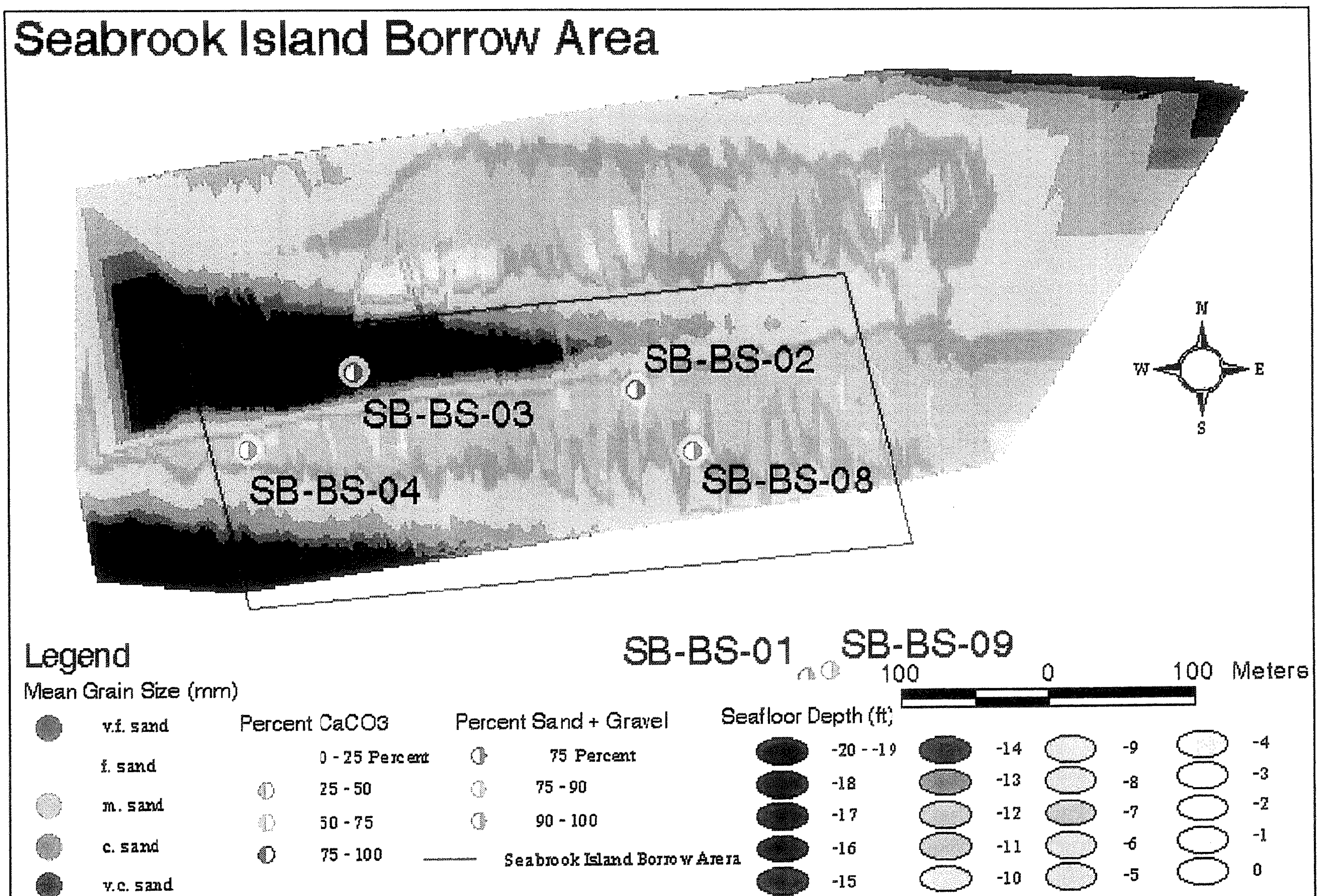

Figure 32. Location of stations sampled at the Seabrook Island borrow site by Coastal Carolina University during the 1996 survey, with summary information on sediment grain size and composition overlaid on the 1996 bathymetry data.

Table 11. Textural parameters of surficial sediments at the Seabrook Island borrow site in June, 1996. Skewness and kurtosis values are provided for each bulk sample (B) and for the non-carbonate fraction (NCF) after shell was removed by acid dissolution.

Sample ID	Latitude (N)	Longitude (W)	% Gravel		% Sand		% Silt/Clay		% CaCO3	Mean Grain Size		Sorting		Skewness		Kurtosis	
			B	NCF	B	NCF	B	NCF	B	B	NCF	B	NCF	B	NCF	B	NCF
SB-BS-01	32 33' 22.75"	80 10" 4.24"	0.10	0.00	99.72	99.81	0.18	0.19	4.36	0.20	0.20	0.46	0.39	-0.64	-0.02	11.69	11.32
SB-BS-03	32 33' 29.64"	80 10' 16.07"	0.14	0.00	99.67	99.80	0.19	0.20	5.64	0.20	0.20	0.50	0.47	-1.40	-0.11	13.67	7.30
SB-BS-02	32 33' 29.18"	80 10' 16.07"	0.12	0.00	99.62	99.73	0.26	0.27	3.74	0.17	0.18	0.44	0.38	-1.99	0.62	29.82	10.98
SB-BS-08	32 33' 27.81"	80 10' 7.15"	0.29	0.00	99.45	99.77	0.26	0.23	11.45	0.23	0.21	0.60	0.50	-1.58	-0.32	10.57	8.57
SB-BS-04	32 33' 27.92"	80 10' 18.93"	0.79	0.00	99.02	99.79	0.19	0.21	9.29	0.20	0.18	0.64	0.45	-3.27	-0.54	24.44	9.94
SB-BS-09	32 33' 22.90"	80 10' 3.59"	3.35	0.00	96.65	99.86	0.00	0.14	12.89	0.21	0.18	0.99	0.46	-2.71	-1.95	10.61	15.71
Composite Average			**0.80**	**0.00**	**99.02**	**99.79**	**0.18**	**0.21**	**7.90**	**0.20**	**0.19**	**0.60**	**0.44**	**-1.93**	**-0.39**	**16.80**	**10.63**

CONCLUSIONS AND RECOMMENDATIONS

Our bathymetric and surficial sediment surveys showed a wide diversity of filling rates and depositional sediment types among the six areas examined (Table 12). However, some trends were clear. With the exception of the Edisto and Seabrook sites, all of the borrow areas were refilling at rates that would require between 5.5-11.8 years to completely refill to pre-dredge profiles. The relatively rapid recovery rate (1.75 yrs) for the Edisto site was probably due to its small size combined with location of this site, which was in a depositional shoal at the southern end of the island. This was also the case for the Seabrook site, which appeared to have largely or completely filled in by the 1996 survey date. Locating sand borrow sites in highly depositional shoals at the southern ends of these islands could increase the rate of refilling since much of the sand located on the beach and in the nearshore zone of these islands would typically be transported in a southerly direction. In contrast, the area that is filling the slowest, Gaskin Banks, is located further offshore and near the center of Hilton Head Island.

The surficial sediments at all of the borrow sites we sampled consisted of clean sands that would be suitable for future nourishment projects. However, sampling at three of the borrow sites (Folly, Hunting, and Joiner) during previous studies indicated that the surficial sands are, or may be, covering one or more lenses of mud. Sands with a high mud content are not considered to be suitable for use in beach nourishment projects (National Research Council, 1995). Thus, these areas would need to be avoided in the future or dredged only to depths above the muddy layer. Additionally, the need to relocate borrow sites for future renourishment projects would result in disturbance of more habitat in the nearshore zone than would be the case if the same borrow area could be re-used over time. Since many of the beach nourishment programs in South Carolina require renourishment at 5-8 year intervals (INTERMAR Task Force, unpublished data), locating future borrow sites in areas that are likely to fill with beach compatible sands during the time period between nourishment projects would be highly desirable.

Table 12. Summary of findings that describe dredging and recovery for South Carolina borrow areas.

Borrow Area	Month/Year Dredged	Calc Vol of Sed Removed (cubic yards)	Avg % Removed Sediment Replaced/Year	Avg Amount Sed Replaced/Year (cubic yards)	% of Removed Sed Replaced by 1996	Estimated Total Years to Fill Completely	Surficial Sediment Characteristics (1996) mean(mm) / %fines
Gaskin Banks	Mar 1990	1,803,862	8%	144,798	51%	11.8	0.18 / 1.1
Joiner Bank	Mar 1990	1,319,844	13%	171,580	83%	7.1	0.19 / 1.6
Hunting Island	Feb & Mar 91	821,339	13%	106,774	68%	7.7	.012 / 4.5
Folly River	May 1993	2,875,022	18%	517,504	60%	5.5	X
Edisto Beach	Apr 1995	157,835	57%	89,966	67%	1.75	.064 / 0.12
Seabrook	X	X	X	X	X	X	0.20 / X
Average of All Areas:		**1,396,580**	**22%**	**206,124**	**66%**	**6.8**	

ACKNOWLEDGEMENTS

We wish to acknowledge and thank several individuals who assisted in this study. They include Paul Crosby and other staff at the U.S. Army Corps of Engineers, Charleston District, who collected and provided all of the bathymetric data for the Folly Beach borrow site, and the crew of the NOAA Ship Ferrel, who assisted in collecting vibracores in the Gaskin Banks and Edisto Island borrow areas. Dr. Tim Kana and staff at Baird and Associates provided reports associated with renourishment projects at Hunting Island, Edisto Island and Seabrook Island. Mr. Eric Olsen and Mr. Chris Creed of Olsen Associates, Inc. provided data and reports that were valuable for interpreting changes at the Hilton Head borrow sites. We would also like to thank Eric Olsen, Chris Creed, Tim Kana, and members of the South Carolina Task Force on Offshore Resources provided for their very helpful technical reviews of a previous draft of this report. Mr. Jeff Trudnak, at the Marine Resources Research Institute GIS center assisted in compiling many of the GIS graphics, and several students at Coastal Carolina University assisted with field work or grain size analyses. They include Jim Ladd, Mike Forte, Lauren Wetzel, Kate Ladd, Wayne Baldwin, Elizabeth Pendelton, Greg French and Brian Batten. Finally, we wish to particularly thank Mr. Tony Giordano and Minerals Management Service INTERMAR program, as well as the South Carolina Task Force on Offshore Resources, for their support of this project. This study was funded, in part, under the Cooperative Agreement No. 14-35-0001-30679 with the Minerals Management Service.

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APPENDIX

Core ID 94-NF-33

Total Depth 113cm

Date cored 8-4-94

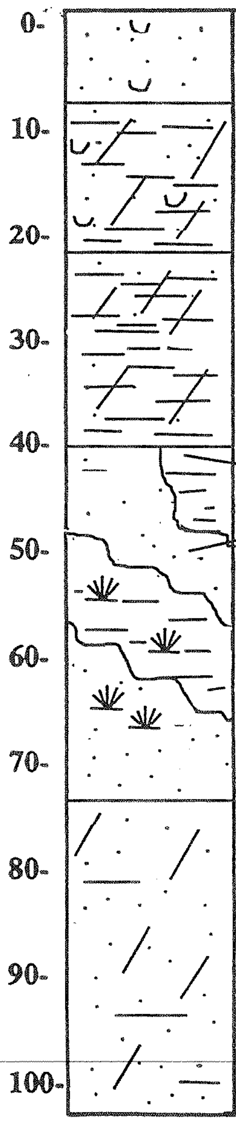
Equipment Rossfelder vibracore

Location 32 28.408'N, 80 16.297'W. Analyst/Date described students, 5-21-96

offshore Edisto

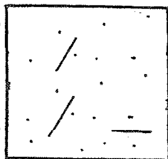
KEY	
Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Sketch



Color	Texture	Sed. Structures	Comments
5Y 4/1	fine sand	85% sand, 15% shell hash	0-7cm Tellina alternata @ 4cm
5GY 4/1	very fine sand to silt	40% silt, 35% sand, 15% shell	7-21cm
5G 4/1	very fine sand to silt	90% silt/clay, 10% sand	21-40cm
5B 5/1, 5G 6/2	v. fine sand	45% sand, 40% silt, 15% organics	40-73cm mixed grey and green clays
5BG 5/1	v. fine sand	80% sand, 30% mud,	73-113cm

Core ID 94-NF-33

	Sketch	Color	Texture	Sed. Structures	Comments
100-				Same unit continued from previous sheet.	
110-					
120-					
130-					
140-					
150-					
160-					
170-					
180-					
190-					
200-					
210-					
220-					
230-					

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Core ID 94-NF-34

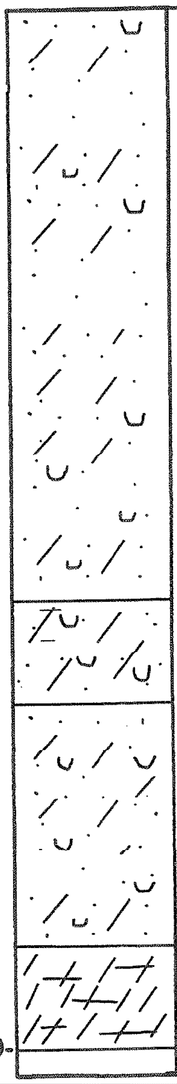
Total Depth 206cm

Date cored 8-4-94

Equipment Rossfelder vibracore

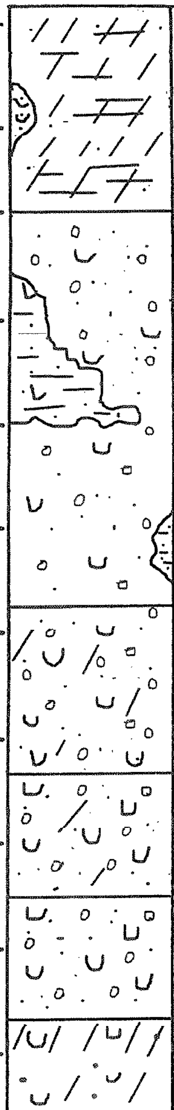
Location 32 27.544'N, 80 15.166'W. Analyst/Date described students, 5-29-96

offshore Edisto Island



Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-		5Y 3/1	v. fine to silt sub-angular	70% sand, 20% mud, 10% shell hash	0-56cm
10-					
20-					
30-					
40-				@40cm increase from 10 to 20% shell hash	
50-					
60-		5Y 3/2	fine sand	65% sand, 25% shell hash, 10% mud.	56-65cm
70-		5Y 3/1	v. fine to silt	50% sand, 30% mud, 20% shell hash	65-90cm
80-					
90-				mud layer, no description	90-100cm
100-					

Core ID 94-NF-34



Depth	Sketch	Color	Texture	Sed. Structures	Comments
100-		5G 4/1	v. fine sand to silt	95% mud, 5% v. fine sand, no shell frag. except for intrusion	100-120cm
110-					
120-		5Y 6/3	coarse to fine sand	65% sand (15% dark-grey, black), 35% shell hash, poorly sorted	120-158cm two intrusions
130-					
140-					
150-					
160-		5Y 5/2	coarse to v. fine	45% sand, 45% shell hash, 10% mud	158-173cm
170-					
180-		5Y 4/1	coarse to v. fine	50% sand, 45% shell, 5% mud, poorly-sorted	173-186cm
190-		2.5Y 5/4	coarse to v. fine sub-angular	55% sand, 45% shell hash, v. poorly sorted	186-197cm
200-		N/3	med. sand to silt	50% mud, 40% shell, 10% sand	197-206cm
210-					
220-					
230-					

CENTER FOR MARINE & WETLAND STUDIES

Core ID NF-94-36

Total Depth 104 cm

Date cored 08-04-94

Equipment R.F. Vibracore

Location 32 24.908' N
80 16.663' W
offshore Edisto

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Analyst/Date described 05-24-94 Gregg & Elizabeth

Depth (cm)	Sketch	Color	Texture	Sed. Structures	Comments
0–10		5Y 5/2	FINE TO MEDIUM SUBANGULAR	3% SHELL 97% SAND	
10–45		5Y 3/2	V. FINE TO FINE SUBANGULAR	15% PHOSPHATIC 3% MUD 5% SHELL	
45–51		5Y 3/2	V. FINE TO V. COARSE	V. POORLY SORTED 35% SHELL HASH	
51–83		5GY 4/1	FINE TO SILT	25% MUD 5% SHELL HASH 70% SAND	LESS MUDDY GRADATIONAL MORE MUDDY
83–87		5Y 5/2	MED. TO FINE	2%MUD 15%SHELL 83%SAND	
87–104		5GY 4/1	FINE TO SILT	15% MUD 5% SHELL HASH 80% SAND	

Core ID NF-94-36 2/2

Total Depth 99 cm

Date cored 08-04-94

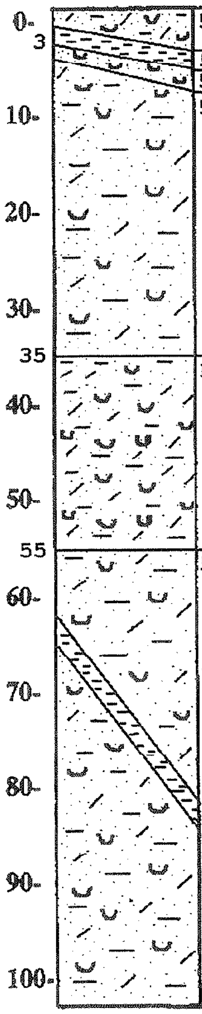
Equipment R.F. VIBRACORE

Location 32 24.908' N
80 16.663' W
offshore Edisto

Analyst/Date described Gregg & Elizabeth 05-24-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds



Depth (cm)	Color	Texture	Sed. Structures	Comments
0-3	5GY 4/1			
3-	5G 4/1	SILT	90%MUD 10%SAND NO SHELL	
	5Y 5/2	FINE-COARSE SUBANGULAR	20%SHELL HASH 80%SAND (NO PHOS) POORLY SORTED	
-35	5GY 4/1	FINE TO SILT	5% MUD 5% SHELL HASH 90% SAND	BIG CLAM SHELL 5 BY 4 cm
35-55	N/3	V. FINE TO FINE	20%MUD 15% SHELL 65% SAND	
55-	5GY 4/1	FINE TO MEDIUM SUBANGULAR	10%SHELL 5% MUD 85% SAND	
	5G 4/1	MUD LAYER		

CENTER FOR MARINE & WETLAND STUDIES

Core ID NF-94-37 1/2

Total Depth 100 cm

Date cored 08-04-94

Equipment R.F. Vibracore

Location 32 24.886' N
80 16.818' W
offshore Edisto

Analyst/Date described J. Ladd 06-17-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Depth (cm)	Sketch	Color	Texture	Sed. Structures	Comments
0–13		2.5Y 5/2	FINE SAND SUBROUNDED POORLY SORTED	3% SHELL HASH 97% SAND	0-13 cm
13–32		2.5Y 5/2	MED. TO FINE SAND SUBANGULAR WELL SORTED	100% SAND	13-32 cm 25 cm 1-4cm SHELL
32–60		2.5Y 6/3	MED. TO FINE SAND SUBROUNDED WELL SORTED	3% SHELL HASH 95% SAND	32-60 cm 47-52 cm FLASER BEDDING MUD LAYERS W/ SAND BETWEEN
60–64		N/4	FINE TO SILT WELL SORTED ROUNDED	15% CLAY 5% SHELL HASH 80% SAND	60-64cm
64–79		2.5Y 6/3	MED. TO FINE ROUNDED WELL SORTED	7% CLAY 93%SAND	64-79cm
79–100		2.5Y 3/1	FINE TO SILT ROUNDED WELL SORTED	25% CLAY 5% SHELL HASH 70% SAND	79-100cm

Core ID NF-94-37

Total Depth 98 cm

Date cored 08-04-94

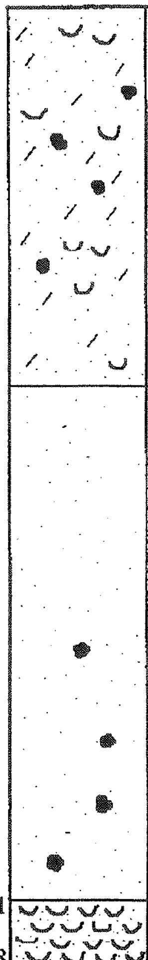
Equipment Ross Feldar Vibracore

Location 32 24.886' N
80 16.818' W
offshore Edisto

Analyst/Date described J. Ladd 06-17-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Depth (cm)	Sketch	Color	Texture	Sed. Structures	Comments
0–38		N/4	FINE TO SILT POORLY SORTED ROUNDED	82% sand 3% SHELL HASH 15% CLAY NO BURROWS FLASER BEDDING	0-38 cm MUD ROLLERS SHELLS 28 cm ILLANALYSIS OBSOLETTA
38–91		2.5Y N/1	VERY FINE TO SILT POORLY SORTED ROUNDED	10% CLAY 5% SHELL HASH 85% SAND	38.91 cm MUD ROLLERS SAND W/ FEW SHELLS
91–98		5Y 5/1	SUB-ANGULAR FINE SAND	5% CLAY 5% SHELL HASH 40% SHELL 40% SAND	91-98 cm SHELL CONCENTRATION

Depth scale: 0- 10- 20- 30- 40- 50- 60- 70- 80- 90- 91 98 100-

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Core ID NF-94-38

Total Depth 105 cm

Date cored 08-04-94

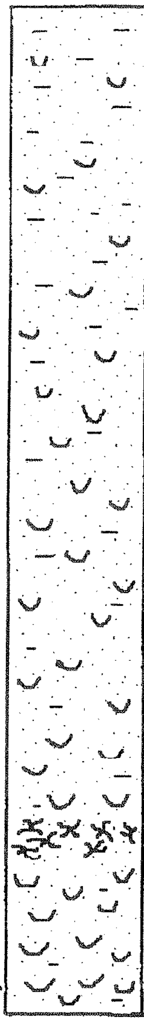
Equipment Ross Feldar Vibracore

Location 32 27.326' N
80 12.989' W
offshore Edisto

Analyst/Date described Gregg French 05-23-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds



Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-		5GY 4/1	FINE TO V. FINE SUB-ROUNDED	10% MUD 70% SAND 20% SHELL HASH	IN TOP 15 cm; CRASSOSTREE VIRGINICA 3 BY 2 cm 2 BY 2 CONGLOMERATE
10-			MORE MUD 10%		
20-			GRADATIONAL		
30-					
40-					
50-			LESS MUD 5%		
60-				5% MUD 30% SHELL HASH	
70-					
80-		5Y 4/1			
90-					
100-					
104					

Core ID NF-94-39 1/2

Total Depth 114 cm

Date cored 08-04-94

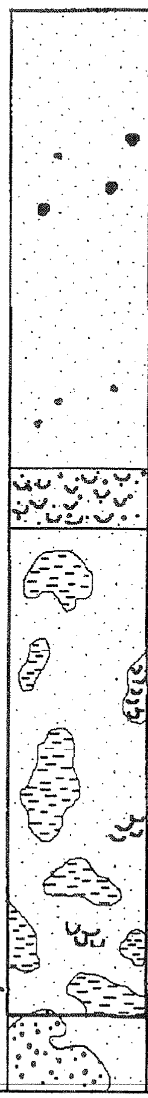
Equipment Ross Feldar Vibracore

Location 32 11.50' N
80 11.50' W
offshore Edisto

Analyst/Date described Gregg French 05-23-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds



Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-		5Y 4/2	SUB-ANGULAR FINE SAND	7%SHELL HASH 93%SAND	
10-					MUD ROLLERS
20-, 30-, 40-					MERCENARIA MERCENARIA
50-		5Y 4/2	FINE TO V. COARSE SUB-ANGULAR	35% SHELL HASH 60%SAND POORLY SORTED	
60-		5Y 4/1	FINE TO MEDIUM SUB-ROUNDED	15% SHELL HASH 5% MUD	SHELL INTRUSIONS
70-, 80-					78 cm SHELL HASH
90-, 100-					92 cm SHELL HASH
					ABUNDANT BURROWING
114-		5Y 6/2	V. COARSE TO MEDIUM SUBANGULAR		COARSE SAND POCKET

CENTER FOR MARINE & WETLAND STUDIES
COASTAL CAROLINA UNIVERSITY

Core ID NF-94-39 2/2

Total Depth 118 cm

Date cored 08-04-94

Equipment Ross Feldar Vibracore

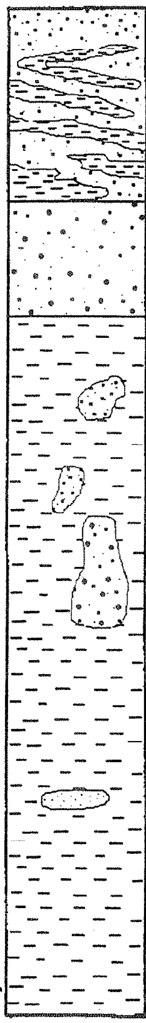
Location 32 27.18' N
80 11.50' W
offshore Edisto

Analyst/Date described J. Ladd 05-23-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Sketch



Depth	Color	Texture	Sed. Structures	Comments
0-	2.5Y 4/2	MED. TO COARSE SUB-ANGULAR		0-19 cm FLASER BEDDING
20-	2.5Y 3/2	COARSE TO SUB-ROUNDED		19-27 cm
30-	5GY 4/1	95% CLAY 5% SAND	STRAIGHT BLUE CLAY	27-118 cm 5% SILT 90% CLAY
40-				BURROWS 34-39 cm 46-48 cm 5GY 6/2 MED. SAND 10% HEAVY
50-				53-60 BURROW 2.5Y 5/2 MED. TO COARSE SAND
60-				
70-				
80-				50 cm SMALL SAND INCLUSION
90-				
100- 118				

Core ID NF-94-40 1/2

Total Depth 105 cm

Date cored 08-04-94

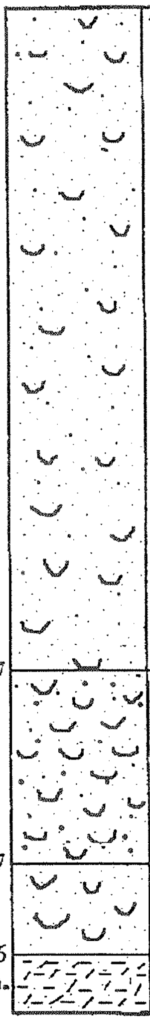
Equipment Ross Feldar Vibrocore

Location 32 27.48' N
80 11.21' W
offshoreEdisto

Analyst/Date described 05-21-96 STUDENTS

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Depth (cm)	Sketch	Color	Texture	Sed. Structures	Comments
0- 10- 20- 30- 40- 50- 60- 67		7.5Y 5/1	MED. TO FINE SUB-ROUNDED	25% SHELL HASH 75% SAND INCREASING CONC. HEAVIES	DINOCARDIUM ROBUSTUM
67 70- 80- 87		5GY 4/1	FINE TO COARSE SUB-ROUNDED TO SUB-ANGULAR	45% SHELL HASH 55% SAND V. POORLY SORTED	
87 90- 96		N/4	FINE TO V. FINE SUB-ANGULAR	15% SHELL HASH 15% SILT & CLAY 70% SAND	
96 100-		N/4	SILT & V. FINE SAND	93% SILT & CLAY 7% FINE SAND	

CENTER FOR MARINE & WETLAND STUDIES

Core ID NF-94-41 1/2

Total Depth 80 cm

Date cored 08 04 94

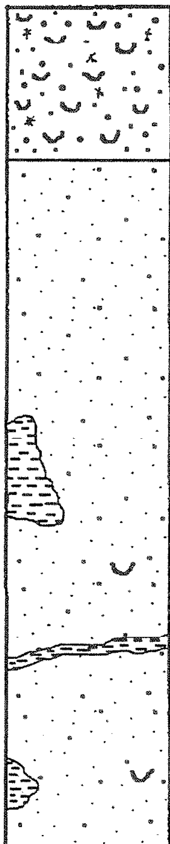
Equipment Ross Feldar Vibracore

Location 32 28.24' N
80 07.62' W

Analyst/Date described 05-22-96 J. Ladd

KEY	
Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Sketch



Depth	Color	Texture	Sed. Structures	Comments
0–14	10YR 4/6	COARSE TO V. COARSE SAND SUB-ANGULAR	35% SHELL HASH 65% SAND 20% HEAVIES	0-14 cm CRASOSTRIA VIRGINICA
14–80	10YR 5/1	COARSE TO FINE SAND WELL SORTED	25% SHELL HASH 5% CLAY 65% SAND 15% HEAVIES	TENNALS (SHELL TYPE) 39-46 cm CLAY INTRUSION TEREBRA DISLOCATA 62 cm CLAY INTRUSION ELINIS SAYANA 73 cm CLAY INTRUSION
80–100				

Depth scale: 0- 10- 20- 30- 40- 50- 60- 70- 80- 90- 100-

Core ID NF-94-41 2/2

Total Depth 83 cm

Date cored 08-04-94

Equipment Ross Feldar Vibracore

Location 32 28.99' N
80 8.46' W
offshore Edisto

Analyst/Date described 05-22-96 J. Ladd, Gregg, Elizabeth

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds

Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-5		5GY 4/1	FINE TO COARSE P. SORTED	35% SHELL HASH 10% CLAY 55% SAND	
5-10		5B 4/1	FINE TO SILT	40% CLAY 50% SAND 10% SHELL HASH	
10-23		5GY 4/1	FINE TO COARSE	35% SHELL HASH 10% CLAY 55%SAND	
23-37		5B 4/1	FINE TO SILT	50% CLAY 10% SHELL 40% SAND	
37-42		5Y 4/3	FINE TO COARSE P. SORTED	50% SHELL HASH 5% MUD 45% QUARTZ	
42-60		N/4	VERY FINE	10%SAND 90% MUD	
60-72		2.5Y 5/2	MED. TO COARSE	50% SHELL HASH 10%MUD 40%SAND	
72-83		5Y 3/1	V. COARSE TO COARSE	40% SHELL HASH 50% SAND 10%MUD	
83-100					

0- 5 10- 20- 23 30- 37 40- 42 50- 60- 70- 72 80- 83 90- 100-

Core ID Gaskin 1

Total Depth 0.35 m

Date cored 12-6-96

Equipment CCU marsh vibracore

Location 32 6.92'N
80 43.88'W

Analyst/Date described Pat Ealy 12-20-96

KEY

- Fine sand
- Med. sand
- Coarse sand
- Pebbles
- Shells
- Silt
- Clay
- Burrows
- Wood Frags.
- Roots
- Peat
- Mud Rollers
- Flaser beds

Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-		N/4- N/3	v.fine silty sand	mod. well sorted, subang-subrnd. grains, 1-2% opaques	
10-					
20-					
30-		5GY 5/1		incr. darker material down core	
40-					
50-					
60-					
70-					
80-					
90-					
100-					

Core ID Gaskin 2

Total Depth 0.63 m

Date cored 12-6-96

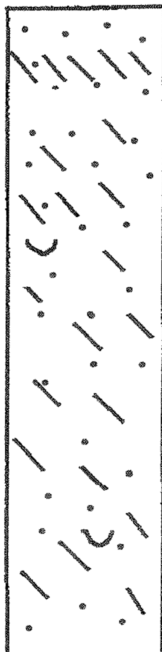
Equipment CCU marsh vibracore

Location 32 6.485'N
80 44.104'W

Analyst/Date described Pat Ealy 12-20-96

KEY

Fine sand	Clay
Med. sand	Burrows
Coarse sand	Wood Frags.
Pebbles	Roots
Shells	Peat
Silt	Mud Rollers
	Flaser beds



Depth	Sketch	Color	Texture	Sed. Structures	Comments
0-					
10-		5Y 6/1	fine silty sand, mod.sorted, subang-subrnd grains	1% fine shell frags. 1-2% opaques	core relatively homogeneous throughout w/ small pockets of darker material
20-					
30-					
40-					
50-					
60-					
70-					
80-					
90-					
100-					